PHILOSOPHICAL

TRANSACTIONS

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCCXXXV.

PART II.

LONDON:

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MDCCCXXXV.

ROYAL MEDALS.

HIS MAJESTY KING WILLIAM THE FOURTH, in restoring the Foundation of the Royal Medals, graciously Commanded a Letter, of which the following is an extract, to be addressed to the Royal Society, through His Royal Highness the DUKE OF SUSSEX, K.G., President:

"Windsor Castle, March 25, 1833.

"It is HIS MAJESTY'S wish,—

"First, That the Two Gold Medals, value of Fifty Guineas each, shall "henceforth be awarded on the day of the Anniversary Meeting of the "Royal Society, on each ensuing year, for the most important discoveries "in any one principal subject or branch of knowledge.

"Secondly, That the subject matter of inquiry shall be previously settled "and propounded by the Council of the Royal Society, three years pre- "ceding the day of such award.

"Thirdly, That Literary Men of all nations shall be invited to afford the "aid of their talents and research. And,

"Fourthly, That for the ensuing three successive years, the said Two "Medals shall be awarded to such important discoveries, or series of in- "vestigations, as shall be sufficiently established, or completed to the "satisfaction of the Council, within the last five years of the days of award, "for the years 1834 and 1835, including the present year, and for which "the Author shall not have previously received an honorary reward.

(Signed) "H. TAYLOR."

The Royal Medals for the year 1833 were awarded to

SIR JOHN FREDERICK WILLIAM HERSCHEL, K.H. F.R.S.,

for his Paper on the Investigation of the Orbits of Revolving Double Stars; and to

PROFESSOR AUGUSTE PYRAME DE CANDOLLE, of Geneva, Foreign Member of the Royal Society,

for his Discoveries and Investigations in Vegetable Physiology.

Those for 1834 were awarded to

JOHN WILLIAM LUBBOCK, ESQ., V.P. & TREAS. R.S.,

for his Papers on the Tides published in the Philosophical Transactions; and to

CHARLES LYELL, ESQ.,

for his Work entitled "Principles of Geology."

Those for the present year have been awarded to

MICHAEL FARADAY, D.C.L.,

for his Investigations and Discoveries contained in the Series of Experimental Researches in Electricity, published in the Philosophical Transactions, and more particularly for the Seventh Series, relating to the definite nature of electro-chemical action; and to

SIR WILLIAM ROWAN HAMILTON, Andrews' Professor of Astronomy in the University of Dublin, and Royal Astronomer of Ireland,

for the Papers published by him in the 16th and 17th volumes of the Transactions of the Royal Irish Academy, entitled "Supplement to an Essay on the Theory of "Systems of Rays," and more particularly for those Investigations at the conclusion of the third and last Supplement, which relate to the discovery of Conical Refraction.

The Council propose to give one of the Royal Medals in the year 1836, to the most important unpublished paper in Astronomy, communicated to the Royal Society for insertion in their Transactions, after the present date (May 13th, 1833,) and prior to the month of June in the year 1836.

The Council also propose to give one of the Royal Medals in the year 1836 to the

most important unpublished paper in Animal Physiology, communicated to the Royal Society for insertion in their Transactions, after the present date (May 13th, 1833,) and prior to the month of June in the year 1836.

The Council propose to give one of the Royal Medals in the year 1837 to the most important unpublished paper in Physics, communicated to the Royal Society for insertion in their Transactions, after the present date (November 27th, 1834,) and prior to the month of June in that year.

The Council also propose to give one of the Royal Medals in the year 1837 to the author of the best paper, to be entitled "Contributions towards a System of Geological Chronology founded on an examination of fossil remains, and their attendant "phenomena," such paper to be communicated to the Royal Society after the present date (December 1st, 1834,) and prior to the month of June 1837:—but in case no paper is presented to the Society fulfilling the conditions implied by the above Resolution, or possessing sufficient merit, the Council propose to give one of the Royal Medals in the year 1837 to the author of the best paper in Geology and Mineralogy, communicated to the Royal Society for insertion in their Transactions after the present date and prior to the month of June in that year.

The Council propose to give one of the Royal Medals in the year 1838 to the most important unpublished paper on Chemistry, communicated to the Royal Society for insertion in their Transactions, after the present date (November 12th, 1835,) and prior to the month of June 1838.

The Council also propose to give one of the Royal Medals in the year 1838 to the most important unpublished paper in Physics, communicated to the Royal Society for insertion in the Philosophical Transactions, after the present date (November 19, 1835,) and prior to the month of June 1838.

CONTENTS.

XIII. *Continuation of the Paper on the Relations between the Nerves of Motion and of Sensation, and the Brain; more particularly on the Structure of the Medulla oblongata and the Spinal Marrow. By Sir* CHARLES BELL, *F.R.S. &c.* page 255

XIV. *Experimental Researches in Electricity.—Tenth Series. By* MICHAEL FARADAY, *D.C.L. F.R.S. Fullerian Prof. Chem. Royal Institution, Corr. Memb. Royal and Imp. Acadd. of Sciences, Paris, Petersburgh, Florence, Copenhagen, Berlin, &c. &c.* 263

XV. *Discussion of Tide Observations made at Liverpool. By* JOHN WILLIAM LUBBOCK, *Esq. V.P. and Treas. R.S.* 275

XVI. *Remarks on the difficulty of distinguishing certain Genera of Testaceous* Mollusca *by their Shells alone, and on the Anomalies in regard to Habitation observed in certain Species. By* JOHN EDWARD GRAY, *Esq. F.R.S. &c.* . . 301

XVII. *On the supposed existence of Metamorphoses in the* Crustacea. *By* J. O. WESTWOOD, *F.L.S. & Sec. Ent. Soc. Communicated by* J. G. CHILDREN, *Esq. Sec. R.S.* 311

XVIII. *On the Ice formed, under peculiar circumstances, at the bottom of running Water. By the Rev.* JAMES FARQUHARSON, *of Alford, F.R.S.* 329

XIX. *Observations on the Theory of Respiration. By* WILLIAM STEVENS, *M.D. D.C.L. Fellow of the Royal College of Physicians in Copenhagen, Fellow of the Royal College of Surgeons in London, &c. &c. Communicated by* W. T. BRANDE, *Esq. V.P.R.S.* 345

XX. *Discovery of the Metamorphosis in the second type of the* Cirripedes, *viz. the* Lepades, *completing the Natural History of these singular Animals, and confirming their affinity with the* Crustacea. *By* J. V. THOMPSON, *F.L.S. Deputy Inspector-General of Hospitals. Communicated by Sir* JAMES MACGRIGOR, *Bart. M.D. F.R.S.* 355

XXI. *On the Double Metamorphosis in the Decapodous* Crustacea, *exemplified in* Cancer Mænas, *Linn. By* J. V. Thompson, *F.L.S. Deputy Inspector-General of Hospitals. Communicated by Sir* James Macgrigor, *Bart. M.D. F.R.S.* 359

Index 365

Appendix.

Meteorological Journal kept at the Apartments of the Royal Society, by order of the President and Council.

ERRATA.

Page 37, line 12. *For* allied to *N. clausa, read* allied to *N. clausa*, Zool. Journal.
Page 37, line 19. For *Murex Rumphius*, Mont., read *Murex Bamfius*, Donov.
Page 37, line 21. For *Fusus corneus* read *Fusus antiquus*, Linn.

PHILOSOPHICAL TRANSACTIONS.

XIII. *Continuation of the Paper on the Relations between the Nerves of Motion and of Sensation, and the Brain; more particularly on the Structure of the Medulla oblongata and the Spinal Marrow.* *By Sir* CHARLES BELL, *F.R.S. &c. &c. &c.*

Received March 25,—Read April 30, 1835.

IN this paper it will be necessary to enter on minute details of the anatomy; but they regard a subject hitherto untouched, although essential to the comprehension of the nervous system, without which, indeed, it could not be said that we had a knowledge of the nerves as a system.

The author has advanced, by slow and laborious researches, from observing the general arrangement of the nerves as they lie in the body, to the investigation of particular nerves and their endowments; and, finally, to the examination of these parts in the centre of the system, the brain and spinal marrow, which enables him to assign the reason of that perfect symmetry which reigns through the whole.

The subjects of his last paper have been examined again and again by dissection, and reviewed in every aspect. They have been found correct in every particular. But they necessarily lead to further investigation: they point more especially to a minute inquiry into the structure of the spinal marrow, and its relations to the encephalon on the one hand, and to the origin of the nerves on the other.

It might be imagined that the author of this paper had, in these inquiries, followed his preconceived notions; but it has not been so. On the contrary, when in search of the explanation of certain phenomena, he discovered a fact in the structure which diverted him from his design, and carried him in a new course of inquiry *.

In an anatomical investigation of so much delicacy, it is necessary, in order to understand the descriptions, that he who follows it by dissection should have the parts presented exactly in the same aspect, and trace them in a prescribed manner. When

* The paper on the Voice was undertaken as a preface to the investigation of the accessory respiratory nerves. In following that subject, the author found it indispensable to deviate into this inquiry, which proves to be the more important of the two.

the anatomist has recognised the parts, and verified the descriptions of the author, he will of course vary his mode of proceeding to satisfy himself.

Lay a portion of the spinal marrow, of two or three inches, on the dissecting board, and pin it so as to look upon the posterior surface of that cord. Begin by making a clean transverse section of it near one extremity, and inspect the newly-divided surface (see Plate III. fig. 1.). The first thing which we distinguish is the cineritious matter in the centre of the medullary. If we introduce the curette into the softer cineritious matter, we can separate the medullary columns (as in figg. 2. & 3.), and we distinguish these parts: the posterior columns, deeply divided by their sulcus; the lateral columns; and the anterior columns.

In making these divisions, directed by the natural sulci and by the cineritious matter, we may soon satisfy ourselves that there is but one absolute bond of union by nervous matter. We find the anterior columns tied together by a sort of commissure, and to that commissure is attached the anterior portion of the posterior columns at two points (fig. 3. D.).

Having contemplated the section of the spinal marrow, we proceed to the dissection by splitting up these columns. We raise the posterior columns together, in one piece; to do which we must divide them at the point of union with the anterior columns (fig. 4. B.). But except at this angle, the whole tract is raised without the slightest breach of its proper surface. When the columns are thus separated, the surfaces are found to be covered with cineritious matter. We have split the cineritious substance, and some of it lies on the lower surface of the part raised, and some on the upper surface of that which is below.

If we now clear away the cineritious substance from the columns below, we shall first discover the two lateral tracts or columns. We see them in their course, regular as nerves. These columns or cords, in this aspect and condition, take a rounded form, although they are of a different shape when packed together in their natural state.

And now may be observed a structure which is not without interest. If we make a slight breach upon the surface of the columns when divested of their cineritious covering, and insinuate the point of the curette, we raise a thin pellicle, like a distinct coat, and which we may separate all round. Having done this, and the remaining surface being smooth, we may pierce it again, and in a similar manner separate a third and a fourth layer, which, smooth and delicate themselves, leave the part below as regular as the natural or exterior surface. It appears that the superficial layers furnish the roots of the higher nerves, and that the lower layers go off into the roots of the nerves as they successively arise.

If we now follow the sensitive or posterior roots of the spinal nerves towards their origins, we find them entering and dispersing in the substance of these lateral columns. Some authors describe these roots as derived from the cineritious matter. This is quite at variance with my dissections. The cineritious matter is not of a con-

sistence or structure into which nerves can be traced: and through the whole column of the spinal marrow, up to the fifth and portio mollis of the seventh nerves of the head, the cineritious matter is superimposed on the columns and nerves *.

Between the lateral columns, the cineritious matter lies deep. Upon raising it, the anterior or motor columns are seen (fig. 4. D, D.). In essential circumstances they resemble the lateral columns, and they are distinct from them. The cineritious matter occupies a portion of the space between them; and as to the remaining part, the line of separation is distinct, and the surfaces are unbroken.

By the manner in which the dissection has been made, the posterior portion of the spinal marrow being raised, as it were, out of the heart of the cord, the remaining parts fall flat, and the lateral and anterior columns separate.

Having distinguished the columns which form the spinal marrow, their natural sulci, their proper connexions, and the distribution of the cineritious substance between them, we have in the next place to observe how these columns are arranged, and what change they undergo in the upper portion of the cord, called medulla oblongata. We approach from below the same parts which we looked upon in their relations with the brain in the last paper.

We must now have before us a portion of the spinal marrow with the medulla oblongata attached to it, and proceed with the dissection.

The parts being presented in the same aspect as before, we raise the two posterior columns, separating them from the others at the intervening cineritious matter. At the back of the medulla oblongata we find the posterior columns diverging, and forming the triangular space of the fourth ventricle; this space is laid open on tearing up the pia mater, which connects the cerebellum with the medulla oblongata. Each of these columns is now seen to consist of two, the outermost the larger, and that towards the central line the smaller, and in shape pyramidal †. Following up these diverging columns, we recognise them to be the processus cerebelli ad medullam oblongatam. These great tracts, which form a large portion of the spinal marrow, are now seen to bear relation to the cerebellum.

The posterior tracts or columns being raised, we have only the lateral and anterior columns, which belong to the cerebrum, to attend to. And here is the interesting part of this communication.

Once more observing the layer of cineritious matter, we brush it off from the

* It is easy to trace the roots of the sensitive portion of the spinal nerve into the lateral column. It should be observed at the same time, that in raising the posterior columns, by insinuating an instrument into the cineritious intermediate substance, there is a more intimate attachment of the medullary substance of the posterior column at its outer edge and in the line of the origins of the nerves. It is not impossible, therefore, that the posterior column may be connected with the sensitive root of the spinal nerves, though hitherto I have not traced the fibres.

† This subdivision of what I have called the posterior column of the spinal marrow is to be traced in the whole length of the spinal marrow.

lateral columns. This grey matter may be traced into the fourth ventricle, extending over the parts to be presently described, and over part of the roots of the fifth pair of nerves. It constitutes one sheet of matter from the cauda equina to the roots of the auditory nerves, and forms a grand septum between the anterior and lateral part of the spinal marrow which belongs to the cerebrum, and the posterior columns which are related to the cerebellum.

Union of the lateral Columns in the Medulla Oblongata.

On brushing away the cineritious matter from the cerebral portion of the spinal marrow, we recognise the two lateral columns. Upwards, or towards the brain, each of these columns has a double termination; first, in the root of the fifth nerve; and secondly, in the union of the columns, or, in other words, in their decussation.

These columns lie separate in the spinal marrow; but having ascended to the medulla oblongata, they fall together, and form one round column something less than half an inch in length. On tracing this united column upwards they are disentangled, but do not separate, for they now constitute those processes of the cerebrum which, in a former paper, we traced down from the back of the crura cerebri (fig. 5. E, E; fig. 6. A, A.).

On observing the portion of the united columns, the appearance is very much that which is presented by the union of the optic nerves; that is, however, rather when the part is thoroughly hardened in spirit: when it is somewhat more pliant, we can trace the filaments of one side into the column on the other side*. The decussation is the most perfect of any to be demonstrated in the brain and nerves.

Reverting to the statement in the former paper, that a septum divides the right and left sensitive tracts where they are seen in the fourth ventricle, and that in tracing that septum downwards it terminates at the point of decussation of these tracts: I have now to add, that the septum does not absolutely terminate, that it splits to permit the oblique course and decussation of the filaments of these columns. Thus separated at the union of the columns, the septa unite again below, and may be followed downwards into that connexion which binds the posterior portion of the spinal marrow to the anterior columns.

It remains a desideratum to know what is the nature of those fibrous septa which intervene and divide the longitudinal tracts of nervous matter. But whatever may be determined on this point, it is obvious that they form a perfect link or bond of union and mechanical strength, extending from the pons to the cauda equina. Around the commissures the fibres of these bands are especially interwoven†.

* Much of the anatomy, as I have here described it, may be made out in the recent parts. But it will be easier and more satisfactory, when the parts are soft, to drop them into spirits, so that the surfaces as they are exposed may be hardened and prepared for further dissection on a succeeding day.

† The true distinctions between the columns in the spinal marrow may be made, as we did those of the medulla oblongata, by observing the splitting of the septa. From the circumstance of the columns scaling off

When the two tracts or columns which descend from the posterior portions of the crura cerebri are transversely divided, where they form the slit of the calamus scriptorius, and when they are dissected down (fig. 4. A, A, B.), we obtain a very interesting view of the back part of the anterior columns (fig. 4. D, D.), or rather of the pyramidal bodies, and their decussation. We see the union and decussation of these bodies before they separate and descend to form the motor columns of the spinal marrow. The motor and sensitive columns,—which were close together in the crura cerebri, and which in their descent were separated in the pons, and by the septum which is continued down from the posterior transverse septum of the pons,—come here again into contact at the point of union and decussation*. The motor columns approach the sensitive columns, but no union takes place; the columns keep their respective courses down the spinal marrow. When we dissect these parts carefully at the back of the medulla oblongata, we may feel, and with sharp eyes we may see, very minute and yet uncommonly strong filaments which run among these parts. We may consider such filaments as a further proof how carefully these textures are guarded against laceration.

When the dissection is carefully made, we have thus a view of the posterior part of the decussation of the pyramidal bodies; and after their decussation we see them separate and descend in the two anterior or motor columns.

Concluding view of the Sensitive and Motor System of Nerves.

If it could be said hitherto that the distribution of the nervous system, more than any other part of the animal structure, evinces design, the conclusion is irresistible, when we perceive that the parts which minister to sensation and motion are arranged with a symmetry beyond what we expect to see in architectural plans or ornaments, where every part is balanced, and each has its counterpart.

It could not be well imagined that sensation and motion belonged to parts separate and dissimilar. Formerly I believed that the nerves of sensation, that is to say, the posterior roots of the spinal nerves, came from the posterior columns of the spinal marrow, and consequently from the cerebellum. Whilst entertaining this belief I found my progress barred, for it appeared to me incomprehensible that motion could result from an organ like the cerebrum, and sensation from the cerebellum, for there was no agreement between them. They conformed neither in size, shape, nor subdivisions. Sensation and volition are necessarily combined in every action of the frame†. Although these influences, of whatever nature they be, are pro-

in regular pellicles, we may else be deceived. On separating, for example, the posterior and lateral columns at the true sulcus of separation, we shall see the minute transverse fibres: which appearance is produced by the splitting of the septum. See the former paper.

* The motor and sensitive columns do not mix or decussate, but only the motor columns with each other, and the sensitive columns with each other.

† This has been illustrated in former papers, and particularly in treating of the actions of the lips.

jected in different directions, and belong to distinct filaments*, they must be finally conjoined and in union. The anatomy conforms to this idea; the cords of communication between the seat of volition and the organs of the body proceed from a centre, run parallel, undergo similar changes, and are blended in their ultimate distribution, as in their central or cerebral relations.

It is pleasing to see that through the labours of members of this Society the principles which have directed the author in the investigation of the human anatomy are likely to be extended in their application, by a correspondence being observed in the arrangement of the nervous tracts through every class of animals possessing volition. It has long appeared to the author that the system does not differ, even in the different classes of animals, although there is much apparent variety in the distribution of the nerves.

When it became a question whether or not *Crustacea* possessed the organ of hearing, the celebrated Scarpa undertook the investigation. With this purpose he did not pry about to discover the external organ of the sense. He looked to the brain, or cerebral ganglion,—recognised the part from which the acoustic nerve should come, according to the analogy of other animals. He found the nerve, and traced it to its destination; that simple rather than imperfect organ, which, but for the circumstance of the auditory nerve in its cavity, might have been supposed too defective in its organization to be capable of receiving the impulse of sounds.

In this manner is the nervous system to be studied; for there is an internal change, in accordance with outward organization, whilst the system or great plan does not vary. There is an endowment in each particular column; it is one through its whole course. An animal, or a class of animals, may have a particular organ developed, and with the external apparatus there is a corresponding or an adjusted condition of the appropriated nerve. Another class may be deficient in the external organization, when we shall in vain look for the accompanying nerve; it is contracted, or hardly visible; but with all this the system is unchanged.

From a more cursory view of the comparative anatomy than others may have taken, this is my conclusion; but my time for such investigations has been given almost exclusively to the human anatomy; and in it I hope it will be granted that the system, as it regards sensation and motion, has been displayed so as to increase the interest of these pursuits, and to direct the studies of the pathologist to beneficial results; much advantage could hardly have been expected by dissection of the brain, even from the utmost ingenuity of research, whilst the very elements of the subject, as regards the natural anatomy, were unknown.

* See the paper on the Nervous Circle.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

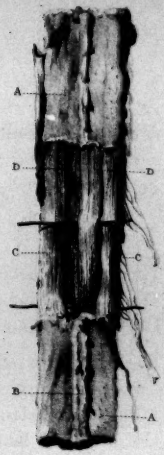


Fig. 5.

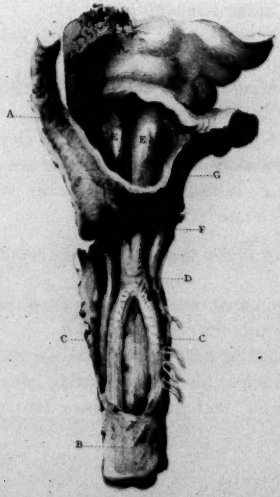
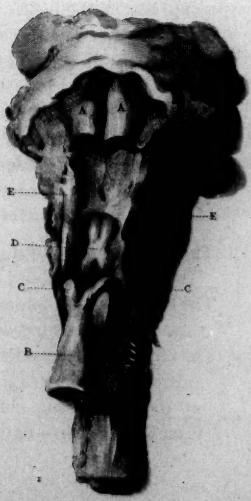


Fig. 6.



Explanation of the PLATE.

PLATE III.

Fig. 1. A transverse section of the spinal marrow, showing the distinctions of the medullary and cineritious substance.

Fig. 2. Shows the section with the medullary columns parted at their natural divisions, viz. by insinuating the curette into the cineritious substance, and opening the sulci.

A. The posterior column.

B, B. The lateral columns.

C. The anterior columns.

Fig. 3. The same parts still further separated, so as to exhibit the connexion between the posterior columns of the spinal marrow and the motor columns. The letters refer to the same parts as in the last figure.

D. The connexion between the posterior and anterior columns.

Fig. 4. In this view the posterior part of the spinal marrow, that which belongs to the cerebellum, is taken away, leaving those columns only which belong to the cerebrum. As the posterior portions (figg. 2. & 3. A.) enter deeply into the spinal marrow, when they are taken away the remaining columns fall flat on the board, and permit an easy separation.

A, A. The cineritious matter which intervenes between the columns belonging to the cerebrum, and those belonging to the cerebellum.

B. Projecting lines where the posterior columns of the spinal marrow were connected with the anterior. (See fig. 3. D.)

C, C. The lateral columns, or sensitive columns, after raising the cineritious substance. Into these the sensitive roots of the spinal nerves are traced.

D, D. A deeper dissection of the cineritious substance exposes here the posterior surface of the anterior or motor columns.

Fig. 5. This figure represents a posterior view of the upper part of the spinal marrow, and the medulla oblongata.

A. The two posterior columns of the spinal marrow being dissected up, they are here represented diverging towards the cerebellum at G.

B. The cineritious matter left on the remaining part of the spinal marrow, after raising the column (A.). The separation of the columns having been made at the intervening cineritious matter, both surfaces have that matter attached to them—both A and B.

C, C. The lateral columns of the spinal marrow (figg. 2. & 3. B, B.), displayed on their posterior surface. They are discovered on raising the cineritious matter B. Into these columns the posterior root of the spinal nerves are traced: they are the columns of sensation.

D. The short column formed by the union of the columns C, C. On dissecting this portion, the decussation of the columns will be seen.

E, E. The same columns which were lateral in the spinal marrow, now continued upwards, and visible in the fourth ventricle without dissection. They ascend under the valvula cerebri and under the corpora quadrigemina, and fall into the crura cerebri. So that, tracing them from above, each of these columns descends from that part of the crus cerebri which is posterior to the corpus nigrum.

F. The origin of the sensitive root of the fifth nerve of the encephalon.

G. The processus cerebelli ad medullam oblongatam.

Fig. 6. This figure represents the further dissection of the parts seen in fig. 5.

A, A. The columns marked E in the former plate. They are divided transversely, and the lower portion folded down, being separated from the parts below by a delicate dissection.

B. These columns folded down.

C, C. The lateral columns of the spinal marrow continued up into B.

D. The union of the anterior columns seen in their posterior aspect. The lateral or sensitive columns, and the anterior or motor columns, are held together at this point. But it appears more for security than reunion. A fine dissection exhibits them quite distinct; and the parts above continuous into the columns of the spinal marrow; each separately.

E, E. The sensitive roots of the fifth pair of nerves.

XIV. *Experimental Researches in Electricity.—Tenth Series.* By MICHAEL FARADAY, *D.C.L. F.R.S. Fullerian Prof. Chem. Royal Institution, Corr. Memb. Royal and Imp. Acadd. of Sciences, Paris, Petersburgh, Florence, Copenhagen, Berlin, &c. &c.*

Received June 16,—Read June 18, 1835.

§ 16. *On an improved form of the Voltaic Battery.* § 17. *Some practical results respecting the construction and use of the Voltaic Battery.*

1119. I HAVE lately had occasion to examine the voltaic trough practically, with a view to improvements in its construction and use; and though I do not pretend that the results have anything like the importance which attaches to the discovery of a new law or principle, I still think they are valuable, and may therefore, if briefly told, and in connexion with former papers, be worthy the approbation of the Royal Society.

§ 16. *On an improved form of the Voltaic Battery.*

1120. In a simple voltaic circuit (and the same is true of the battery) the chemical forces which, during their activity, give power to the instrument, are generally divided into two portions; the one of these is exerted locally, whilst the other is transferred round the circle (947. 996.); the latter constitutes the electric current of the instrument, whilst the former is altogether lost or wasted. The ratio of these two portions of power may be varied to a great extent by the influence of circumstances: thus, in a battery not closed, *all* the action is local; in one of the ordinary construction, *much* is in circulation when the extremities are in communication; and in the perfect one, which I have described (1001.), *all* the chemical power circulates and becomes electricity. By referring to the quantity of zinc dissolved from the plates (865. 1126.), and the quantity of decomposition effected in the volta-electrometer (711. 1126.) or elsewhere, the proportions of the local and transferred actions under any particular circumstances can be ascertained, and the efficacy of the voltaic arrangement, or the waste of chemical power at its zinc plates, be accurately determined.

1121. If a voltaic battery were constructed of zinc and platina, the latter metal surrounding the former, as in the double copper arrangement, and the whole being excited by dilute sulphuric acid, then no insulating divisions of glass, porcelain, or air would be required between the contiguous platina surfaces; and, provided these did not touch metallically, the same acid which, being between the zinc and platina, would excite the battery into powerful action, would, between the two surfaces of

platina, produce no discharge of the electricity, nor cause any diminution of the power of the trough. This is a necessary consequence of the resistance to the passage of the current which I have shown occurs at the place of decomposition (1007. 1011.); for that resistance is fully able to stop the current, and therefore act as insulation to the electricity of the contiguous plates, inasmuch as the current which tends to pass between them never has a higher intensity than that due to the action of a single pair.

1122. If the metal surrounding the zinc be copper (1045.), and if the acid be nitro-sulphuric acid (1020.), then a slight discharge between the two contiguous coppers does take place, provided there be no other channel open by which the forces may circulate; but when such a channel is permitted, the return discharge of which I speak is exceedingly diminished, in accordance with the principles laid down in the eighth series of these Researches.

1123. Guided by these principles I was led to the construction of a voltaic trough, in which the coppers, passing round both surfaces of the zincs, as in WOLLASTON'S construction, should not be separated from each other except by an intervening thickness of paper, or in some other way, so as to prevent metallic contact, and should thus constitute an instrument compact, powerful, economical, and easy of use. On examining, however, what had been done before, I found that the new trough was in all essential respects the same as that invented and described by Dr. HARE, Professor in the University of Pennsylvania, to whom I have great pleasure in referring it.

1124. Dr. HARE has fully described his trough*. In it the contiguous copper plates are separated by thin veneers of wood, and the acid is poured on to, or off, the plates by a quarter revolution of an axis, to which both the trough containing the plates, and another trough to collect and hold the liquid, are fixed. This arrangement I have found the most convenient of any, and have therefore adopted it. My zinc plates were cut from rolled metal, and when soldered to the copper plates had the form delineated, fig. 1. These were then bent over a gauge into the form fig. 2, and when packed in the wooden box constructed to receive them, were arranged as in fig. 3†, little plugs of cork being used to keep the zinc plates from touching the

Fig. 1.

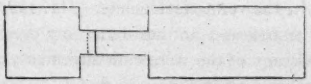
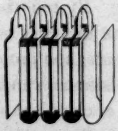


Fig. 2.

Fig. 3.



copper plates, and a single or double thickness of cartridge paper being interposed

* Philosophical Magazine, 1824, vol. lxiii. p. 241; or SILLIMAN'S Journal, vol. vii. See also a previous paper by Dr. HARE, Annals of Philosophy, 1821, vol. i. p. 329, in which he speaks of the non-necessity of insulation between the coppers.

† The papers between the coppers are, for the sake of distinctness, omitted in the figure.

between the contiguous surfaces of copper to prevent them from coming in contact. Such was the facility afforded by this arrangement, that a trough of forty pairs of plates could be unpacked in five minutes, and repacked again in half an hour; and the whole series was not more than fifteen inches in length.

1125. This trough, of forty pairs of plates three inches square, was compared, as to the ignition of a platina wire, the discharge between points of charcoal, the shock on the human frame, &c., with forty pairs of four-inch plates having double coppers, and used in porcelain troughs divided into insulating cells, the strength of the acid employed to excite both being the same. In all these effects the former appeared quite equal to the latter. On comparing a second trough of the new construction, containing twenty pairs of four-inch plates, with twenty pairs of four-inch plates in porcelain troughs, excited by acid of the same strength, the new trough appeared to surpass the old one in producing these effects, especially in the ignition of wire.

1126. In these experiments the new trough diminished in its energy much more rapidly than the one on the old construction, and this was a necessary consequence of the smaller quantity of acid used to excite it, which in the case of the forty pairs new construction was only one seventh part of that used for the forty pairs in the porcelain troughs. To compare, therefore, both forms of the voltaic trough in their decomposing powers, and to obtain accurate data as to their relative values, experiments of the following kind were made. The troughs were charged with a known quantity of acid of a known strength; the electric current was passed through a volta-electrometer (711.) having electrodes 4 inches long and 2·3 inches in width, so as to oppose as little obstruction as possible to the current; the gases evolved were collected and measured, and gave the quantity of water decomposed. Then the whole of the charge used was mixed together, and a known part of it analysed, by being precipitated and boiled with excess of carbonate of soda, and the precipitate well washed, dried, ignited, and weighed. In this way the quantity of metal oxidized and dissolved by the acid was ascertained; and the part removed from each zinc plate, or from all the plates, could be estimated and compared with the water decomposed in the volta-electrometer. To bring these to one standard of comparison, I have reduced the results so as to express the loss at the plates in equivalents of zinc for the equivalent of water decomposed at the volta-electrometer: I have taken the equivalent number of water as 9, and of zinc as 32·5, and have considered 100 cubic inches of the mixed oxygen and hydrogen, as they were collected over a pneumatic trough, to result from the decomposition of 12·68 grains of water.

1127. The acids used in these experiments were three,—sulphuric, nitric, and muriatic. The sulphuric acid was strong oil of vitriol; one cubical inch of it was equivalent to 486 grains of marble. The nitric acid was very nearly pure; one cubical inch dissolved 150 grains of marble. The muriatic acid was also nearly pure, and one cubical inch dissolved 108 grains of marble. These were always mixed with water by volumes, the standard of volume being a cubical inch.

1128. An acid was prepared consisting of 200 parts water, 4½ parts sulphuric acid, and 4 parts nitric acid; and with this both my trough, containing forty pairs of three-inch plates, and four porcelain troughs, arranged in succession, each containing ten pairs of plates with double coppers four inches square, were charged. These two batteries were then used in succession, and the action of each was allowed to continue for twenty or thirty minutes, until the charge was nearly exhausted, the connexion with the volta-electrometer being carefully preserved during the whole time, and the acid in the troughs occasionally mixed together. In this way the former trough acted so well, that for each equivalent of water decomposed in the volta-electrometer only from 2 to 2·5 equivalents of zinc were dissolved from each plate. In four experiments the average was 2·21 equivalents for each plate, or 88·4 for the whole battery. In the experiments with the porcelain troughs, the equivalents of consumption at each plate were 3·54, or 141·6 for the whole battery. In a perfect voltaic battery of forty pairs of plates (991. 1001.) the consumption would have been one equivalent for each zinc plate, or forty for the whole.

1129. Similar experiments were made with two voltaic batteries, one containing twenty pairs of four-inch plates, arranged as I have described (1124.), and the other twenty pairs of four-inch plates in porcelain troughs. The average of five experiments with the former was a consumption of 3·7 equivalents of zinc from each plate, or 74 from the whole: the average of three experiments with the latter was 5·5 equivalents from each plate, or 110 from the whole: to obtain this conclusion, two experiments were struck out, which were much against the porcelain troughs, and in which some unknown deteriorating influence was supposed to be accidentally active. In all the experiments, care was taken not to compare *new* and *old* plates together, as that would have introduced serious errors into the conclusions (1146.).

1130. When ten pairs of the new arrangement were used, the consumption of zinc at each plate was 6·76 equivalents, or 67·6 for the whole. With ten pairs of the common construction, in a porcelain trough, the zinc oxidized was, upon an average, 15·5 equivalents each plate, or 155 for the entire trough.

1131. No doubt, therefore, can remain of the equality or even the great superiority of this form of voltaic battery over the best previously in use, namely, that with double coppers, in which the cells are insulated. The insulation of the coppers may therefore be dispensed with; and it is that circumstance which principally permits of such other alterations in the construction of the trough as gives it its practical advantages.

1132. The advantages of this form of trough are very numerous and great. i. It is exceedingly compact, for 100 pairs of plates need not occupy a trough of more than three feet in length. ii. By Dr. HARE's plan of making the trough turn upon copper pivots which rest upon copper bearings, the latter afford *fixed* terminations; and these I have found it very convenient to connect with two cups of mercury, fastened in the front of the stand of the instrument. These fixed terminations give

the great advantage of arranging an apparatus to be used in connexion with the battery *before* the latter is put into action. iii. The trough is put into readiness for use in an instant, a single jug of dilute acid being sufficient for the charge of 100 pairs of four-inch plates. iv. On making the trough pass through a quarter of a revolution, it becomes active, and the great advantage is obtained of procuring for the experiment the effect of the *first contact* of the zinc and acid, which is twice or sometimes even thrice that which the battery can produce a minute or two after (1036. 1150.). v. When the experiment is completed, the acid can be at once poured from between the plates, so that the battery is never left to waste during an unconnected state of its extremities; the acid is not unnecessarily exhausted; the zinc is not uselessly consumed; and, besides avoiding these evils, the charge is mixed and rendered uniform, which produces a great and good result (1039.); and, upon proceeding to a second experiment, the important effect of *first contact* is again obtained. vi. The saving of zinc is very great. It is not merely that, whilst in action, the zinc performs more voltaic duty (1128. 1129.), but *all* the destruction which takes place with the ordinary forms of battery between the experiments is prevented. This saving is of such extent, that I estimate the zinc in the new form of battery to be thrice as effective as that in the ordinary form. vii. The importance of this saving of metal is not merely that the value of the zinc is saved, but that the battery is much lighter and more manageable; and also that the surfaces of the zinc and copper plates may be brought much nearer to each other when the battery is constructed, and remain so until it is worn out: the latter is a very important advantage (1148.). viii. Again, as, in consequence of the saving, thinner plates will perform the duty of thick ones, rolled zinc may be used; and I have found rolled zinc superior to cast zinc in action; a superiority which I incline to attribute to its greater purity (1144.). ix. Another advantage is obtained in the economy of the acid used, which is proportionate to the diminution of the zinc dissolved. x. The acid also is more easily exhausted, and is in such small quantity that there is never any occasion to return an old charge into use. Such old acid, whilst out of use, often dissolves portions of copper from the black flocculi usually mingled with it, which are derived from the zinc; now any portion of copper in solution in the charge does great harm, because, by the *local* action of the acid and zinc, it tends to precipitate upon the latter, and diminish its voltaic efficacy (1145.). xi. By using a due mixture of nitric and sulphuric acid for the charge (1139.), no gas is evolved from the troughs; so that a battery of several hundred pairs of plates may, without inconvenience, be close to the experimenter. xii. If, during a series of experiments, the acid becomes exhausted, it can be withdrawn, and replaced by other acid with the utmost facility; and after the experiments are concluded, the great advantage of easily washing the plates is at command. And it appears to me, that in place of making, under different circumstances, mutual sacrifices of comfort, power, and economy, to obtain a desired end, all are at once obtained by Dr. HARE's form of trough.

1133. But there are some disadvantages which I have not yet had time to overcome, though I trust they will finally be conquered. One is the extreme difficulty of making a wooden trough constantly water-tight under the alternations of wet and dry to which the voltaic instrument is subject. To remedy this evil, Mr. NEWMAN is now engaged in obtaining porcelain troughs. The other disadvantage is a precipitation of copper on the zinc plates. It appears to me to depend mainly on the circumstance that the papers between the coppers retain acid when the trough is emptied; and that this acid slowly acting on the copper, forms a salt, which gradually mingles with the next charge, and is reduced on the zinc plate by the local action (1120.): the power of the whole battery is then reduced. I expect that by using slips of glass to separate the coppers at their edges, their contact can be sufficiently prevented, and the space between them be left so open that the acid of a charge can be poured and washed out, and so be removed from *every part* of the trough when the experiments in which it is used are completed.

1134. The actual superiority of the troughs which I have constructed on this plan, I believe to depend, first and principally, on the closer approximation of the zinc and copper surfaces;—in my troughs they are only one tenth of an inch apart (1148.);—and, next, on the superior quality of the rolled zinc above the cast zinc used in the construction of the ordinary pile. It cannot be that insulation between the contiguous coppers is a disadvantage, but I do not find that it is any advantage; for when, with both the forty pairs of three-inch plates and the twenty pairs of four-inch plates, I used papers well imbibed with wax*, these being so large that when folded at the edges they wrapped over each other, so as to make cells as insulating as those of the porcelain troughs, still no sensible advantage in the chemical action was obtained.

1135. As, upon principle, there must be a discharge of part of the electricity from the edges of the zinc and copper plates at the sides of the trough, I should prefer, and intend having, troughs constructed with a plate or plates of crown glass at the sides of the trough: the bottom will need none, though to glaze that and the ends would be no disadvantage. The plates need not be fastened in, but only set in their places; nor need they be in large single pieces.

§ 17. *Some practical results respecting the construction and use of the Voltaic Battery.*

1136. The electro-chemical philosopher is well acquainted with some practical results obtained from the voltaic battery by MM. GAY-LUSSAC and THENARD, and given in the first forty-five pages of their 'Recherches Physico-Chimiques'. Although the following results are generally of the same nature, yet the advancement made in this branch of science of late years, the knowledge of the definite action of electricity,

* A single paper thus prepared could insulate the electricity of a trough of forty pairs of plates.

and the more accurate and philosophical mode of estimating the results by the equivalents of zinc consumed, will be their sufficient justification.

1137. *Nature and strength of the acid.*—My battery of forty pairs of three-inch plates was charged with acid consisting of 200 parts water and 9 oil of vitriol. Each plate lost, in the average of the experiments, 4·66 equivalents, or the whole battery 186·4 equivalents, of zinc, for the equivalent of water decomposed in the volta-electrometer. Being charged with a mixture of 200 water and 16 of the muriatic acid, each plate lost 3·8, or the whole battery 152, equivalents of zinc for the water decomposed. Being charged with a mixture of 200 water and 8 nitric acid, each plate lost 1·85, or the whole battery 74·16, equivalents of zinc for one equivalent of water decomposed. The sulphuric and muriatic acids evolved much hydrogen at the plates in the trough; the nitric acid no gas whatever. The relative strengths of the original acids have already been given (1127.); but a difference in that respect makes no important difference in the results when thus expressed by equivalents (1140.).

1138. Thus nitric acid proves to be the best for this purpose: its superiority appears to depend upon its favouring the electrolization of the liquid in the cells of the trough upon the principles already explained (905. 973. 1022.), and consequently favouring the transmission of the electricity, and therefore the production of transferable power (1120.).

1139. The addition of nitric acid might, consequently, be expected to improve sulphuric and muriatic acids. Accordingly, when the same trough was charged with a mixture of 200 water, 9 oil of vitriol, and 4 nitric acid, the consumption of zinc was at each plate 2·786, and for the whole battery 111·5, equivalents. When the charge was 200 water, 9 oil of vitriol, and 8 nitric acid, the loss per plate was 2·26, or for the whole battery 90·4, equivalents. When the trough was charged with a mixture of 200 water, 16 muriatic acid, and 6 nitric acid, the loss per plate was 2·11, or for the whole battery 84·4, equivalents. Similar results were obtained with my battery of twenty pairs of four-inch plates (1129.). Hence it is evident that the nitric acid was of great service when mingled with the sulphuric acid; and the charge generally used after this time for ordinary experiments consisted of 200 water, 4½ oil of vitriol, and 4 nitric acid.

1140. It is not to be supposed that the different strengths of the acids produced the differences above; for within certain limits I found the electrolytic effects to be nearly as the strengths of the acids, so as to leave the expression of force, when given in equivalents, nearly constant. Thus, when the trough was charged with a mixture of 200 water and 8 nitric acid, each plate lost 1·854 equivalent of zinc. When the charge was 200 water and 16 nitric acid, the loss per plate was 1·82 equivalent. When it was 200 water and 32 nitric acid, the loss was 2·1 equivalents. The differences here are not greater than happen from unavoidable irregularities, depending on other causes than the strength of acid.

1141. Again, when a charge consisting of 200 water, 4½ oil of vitriol, and 4 nitric

acid was used, each zinc plate lost 2·16 equivalents; when the charge with the same battery was 200 water, 9 oil of vitriol, and 8 nitric acid, each zinc plate lost 2·26 equivalents.

1142. I need hardly say that no copper is dissolved during the regular action of the voltaic trough. I have found that much ammonia is formed in the cells when nitric acid, either pure or mixed with sulphuric acid, is used. It is produced in part as a secondary result at the cathodes (663.) of the different portions of fluid constituting the necessary electrolyte, in the cells.

1143. *Uniformity of the charge.*—This is a most important point, as I have already shown experimentally (1042. &c.). Hence one great advantage of Dr. HARE's mechanical arrangement of his trough.

1144. *Purity of the zinc.*—If pure zinc could be obtained, it would be very advantageous in the construction of the voltaic apparatus (998.). Most zincs, when put into dilute sulphuric acid, leave more or less of an insoluble matter upon the surface in the form of a crust, which contains various metals, as copper, lead, zinc, iron, cadmium, &c., in the metallic state. Such particles, by discharging part of the transferable power, render it, as to the whole battery, local; and so diminish the effect. As an indication connected with the more or less perfect action of the battery, I may mention that no gas ought to rise from the zinc plates. The more gas which is generated upon these surfaces, the greater is the local action and the less the transferable force. The investing crust is also inconvenient, by preventing the displacement and renewal of the charge upon the surface of the zinc. Such zinc as, dissolving in the cleanest manner in a dilute acid, dissolves also the slowest, is the best; zinc which contains much copper should especially be avoided. I have generally found rolled Liege or MOSSELMAN's zinc the purest; and to that circumstance attribute in part the advantage of the new battery (1134.).

1145. *Foulness of the zinc plates.*—After use, the plates of a battery should be cleaned from the metallic powder upon their surfaces, especially if they are employed to obtain the laws of action of the battery itself. This precaution was always attended to with the porcelain trough batteries in the experiments described (1125., &c.). If a few foul plates are mingled with many clean ones, they make the action in the different cells irregular, and the transferable power is accordingly diminished, whilst the local and wasted power is increased. No old charge containing copper should be used to excite a battery.

1146. *New and old plates.*—I have found voltaic batteries far more powerful when the plates were new than when they have been used two or three times; so that a new and a used battery cannot be compared together, or even a battery with itself on the first and after times of use. My trough of twenty pairs of four-inch plates, charged with acid consisting of 200 water, 4½ oil of vitriol, and 4 nitric acid, lost, upon the first time of being used, 2·32 equivalents per plate. When used after the fourth time with the same charge, the loss was from 3·26 to 4·47 equivalents per plate; the average

being 3·7 equivalents. The first time the forty pair of plates (1124.) were used, the loss at each plate was only 1·65 equivalent; but afterwards it became 2·16, 2·17, 2·52. The first time twenty pair of four-inch plates in porcelain troughs were used, they lost, per plate, only 3·7 equivalents; but after that, the loss was 5·25, 5·36, 5·9 equivalents. Yet in all these cases the zincs had been well cleaned from adhering copper, &c., before each trial of power.

1147. With the rolled zinc the fall in force soon appeared to become constant, i. e. to proceed no further. But with the cast zinc plates belonging to the porcelain troughs, it appeared to continue, until at last, with the same charge, each plate lost above twice as much zinc for a given amount of action as at first. These troughs were, however, so irregular that I could not always determine the circumstances affecting the amount of electrolytic action.

1148. *Vicinity of the copper and zinc.*—The importance of this point in the construction of voltaic arrangements, and the greater power, as to immediate action, which is obtained when the zinc and copper surfaces are near to each other than when removed further apart, are well known. I find that the power is not only greater on the instant, but also that the sum of transferable power, in relation to the whole sum of chemical action at the plates, is much increased. The cause of this gain is very evident. Whatever tends to retard the circulation of the transferable force, (i. e. the electricity,) diminishes the proportion of such force, and increases the proportion of that which is local (996. 1120.). Now the liquid in the cells possesses this retarding power, and therefore acts injuriously, in greater or less proportion, according to the quantity of it between the zinc and copper plates, i. e. according to the distances between their surfaces. A trough, therefore, in which the plates are only half the distance asunder at which they are placed in another, will produce more transferable, and less local, force than the latter; and thus, because the electrolyte in the cells can transmit the current more readily, both the intensity and quantity of electricity is increased for a given consumption of zinc. To this circumstance mainly I attribute the superiority of the trough I have described (1134.).

1149. The superiority of *double coppers* over single plates also depends in part upon diminishing the resistance offered by the electrolyte between the metals. For, in fact, with double coppers the sectional area of the interposed acid becomes nearly double that with single coppers, and therefore it more freely transfers the electricity. Double coppers are, however, effective, mainly because they virtually double the acting surface of the zinc, or nearly so; for in a trough with single copper plates and the usual construction of cells, that surface of zinc which is not opposed to a copper surface is thrown almost entirely out of voltaic action, yet the acid continues to act upon it and the metal is dissolved, producing very little more than local effect (947. 996.). But when by doubling the copper, that metal is opposed to the second surface of the zinc plate, then a great part of the action upon the latter is converted into transferable force, and thus the power of the trough as to quantity of electricity is highly exalted.

1150. *First immersion of the plates.*—The great effect produced at the first immersion of the plates, (apart from their being new or used (1146.),) I have attributed elsewhere to the unchanged condition of the acid in contact with the zinc plate (1003. 1037.): as the acid becomes neutralized, its exciting power is proportionably diminished. HARE's form of trough secures much advantage of this kind, by mingling the liquid, and bringing what may be considered as a fresh surface of acid against the plates every time it is used immediately after a rest.

1151. *Number of plates**.—The most advantageous number of plates in a battery used for chemical decomposition, depends almost entirely upon the resistance to be overcome at the place of action; but whatever that resistance may be, there is a certain number which is more economical than either a greater or a less. Ten pairs of four-inch plates in a porcelain trough of the ordinary construction, acting in the volta-electrometer (1126.) upon dilute sulphuric acid of spec. grav. 1·314, gave an average consumption of 15·4 equivalents per plate, or 154 equivalents on the whole. Twenty pairs of the same plates, with the same acid, gave only a consumption of 5·5 per plate, or 110 equivalents upon the whole. When forty pairs of the same plates were used, the consumption was 3·54 equivalents per plate, or 141·6 upon the whole battery. Thus the consumption of zinc arranged as twenty plates was more advantageous than if arranged either as ten or as forty.

1152. Again, ten pairs of my four-inch plates (1129.) lost 6·76 each, or the whole ten 67·6 equivalents of zinc, in effecting decomposition; whilst twenty pairs of the same plates, excited by the same acid, lost 3·7 equivalents each, or on the whole 74 equivalents. In other comparative experiments of numbers, ten pairs of the three-inch plates (1125.) lost 3·725, or 37·25 equivalents upon the whole; whilst twenty pairs lost 2·53 each, or 50·6 in all; and forty pairs lost on an average 2·21, or 88·4 altogether. In both these cases, therefore, increase of numbers had not been advantageous as to the effective production of *transferable chemical power* from the *whole quantity of chemical force* active at the surfaces of excitation (1120.).

1153. But if I had used a weaker acid or a worse conductor in the volta-electrometer, then the number of plates which would produce the most advantageous effect would have risen; or if I had used a better conductor than that really employed in the volta-electrometer, I might have reduced the number even to one; as, for instance, when a thick wire is used to complete the circuit (865., &c.). And the cause of these variations is very evident, when it is considered that each successive plate in the voltaic apparatus does not add anything to the *quantity* of transferable power or electricity which the first plate can put into motion, provided a good conductor be present, but tends only to exalt the *intensity* of that quantity, so as to make it more able to overcome the obstruction of bad conductors (994. 1158.).

1154. *Large or small plates*†.—The advantageous use of large or small plates for electrolyzations will evidently depend upon the facility with which the transferable

* GAY-LUSSAC and THENARD, Recherches Physico-Chimiques, tom. i. p. 29. † Ibid.

power or electricity can pass. If in a particular case the most effectual number of plates is known (1151.), then the addition of more zinc would be most advantageously made in increasing the *size* of the plates, and not their *number*. At the same time, large increase in the size of the plates would raise in a small degree the most favourable number.

1155. Large and small plates should not be used together in the same battery: the small ones occasion a loss of the power of the large ones, unless they be excited by an acid proportionably more powerful; for with a certain acid they cannot transmit the same portion of electricity in a given time which the same acid can evolve by action on the larger plates.

1156. *Simultaneous decompositions.*—When the number of plates in a battery much surpasses the most favourable proportion (1151—1153.), two or more decompositions may be effected simultaneously with advantage. Thus my forty pairs of plates (1124.) produced in one volta-electrometer 22·8 cubic inches of gas. Being recharged exactly in the same manner, they produced in each of two volta-electrometers 21 cubical inches. In the first experiment the whole consumption of zinc was 88·4 equivalents, and in the second only 48·28 equivalents, for the whole of the water decomposed in both volta-electrometers.

1157. But when the twenty pairs of four-inch plates (1129.) were tried in a similar manner, the results were in the opposite direction. With one volta-electrometer 52 cubic inches of gas were obtained; with two, only 14·6 cubic inches from each. The quantity of charge was not the same in both cases, though it was of the same strength; but on rendering the results comparative by reducing them to equivalents (1126.), it was found that the consumption of metal in the first case was 74, and in the second case 97, equivalents for the *whole* of the water decomposed. These results of course depend upon the same circumstances of retardation, &c., which have been referred to in speaking of the proper number of plates (1151.).

1158. That the *transferring*, or, as it is usually called, *conducting*, *power* of an electrolyte which is to be decomposed, or other interposed body, should be rendered as good as possible*, is very evident (1020. 1120.). With a perfectly good conductor and a good battery, nearly all the electricity is passed, i. e. *nearly all* the chemical power becomes transferable, even with a single pair of plates (867.). With an interposed non-conductor none of the chemical power becomes transferable. With an imperfect conductor more or less of the chemical power becomes transferable as the circumstances favouring the transfer of forces across the imperfect conductor are exalted or diminished: these circumstances are, actual increase or improvement of the conducting power, enlargement of the electrodes, approximation of the electrodes, and increased intensity of the passing current.

1159. The introduction of common spring water in place of one of the volta-electrometers used with twenty pairs of four-inch plates (1156.) caused such obstruction

* Gay-Lussac and Thenard, Recherches Physico-Chimiques, tom. i. pp. 13, 15, 22.

as not to allow one fifteenth of the transferable force to pass which would have circulated without it. Thus fourteen fifteenths of the available force of the battery were destroyed, being converted into local force, (which was rendered evident by the evolution of gas from the zincs,) and yet the platina electrodes in the water were three inches long, nearly an inch wide, and not a quarter of an inch apart.

1160. These points, i. e. the increase of conducting power, the enlargement of the electrodes, and their approximation, should be especially attended to in *volta-electrometers*. The principles upon which their utility depend are so evident that there can be no occasion for further development of them here.

Royal Institution,
October 11, 1834.

XV. *Discussion of Tide Observations made at Liverpool. By* John William Lubbock, *Esq. V.P. and Treas. R.S.*

Received and Read June 18, 1835.

By permission of the British Association for the Advancement of Science, I am enabled to present to the Society a discussion by M. Dessiou * of 13,327 observations of the tides made at Liverpool between the 1st of January 1774 and the 31st of December 1792. These observations, which were made by Mr. Hutchinson, Dockmaster at that place, belong to the Lyceum at Liverpool, and they were granted with the greatest readiness and liberality by the Committee of that Institution, upon the application of Mr. Whewell and myself, for the purposes of the present inquiry.

Mr. Hutchinson recorded the *solar time* of high water, and the height of the tide in feet and inches, at the Custom-House Dock gates, together with the direction and strength of the wind, and the state of the weather; also, during a great portion of the time, the height of the barometer and thermometer.

The following note is prefixed to the first book of these valuable observations: "These five years' observations upon the tides were made from solar time, and the winds from the true meridian, and their velocity judged according to Mr. Smeaton's rule, our great storms going at the rate of sixty miles an hour; the thermometer kept in-doors, at the head of a staircase four stories high; by William Hutchinson, at the Old Dock gates, Liverpool."

The following note is appended at the conclusion: "These observations, made from the beginning of 1768 to August 10, 1793, make twenty-five years, seven months and ten days, which I have given to our Library, exclusive of the 3000 observations given to Messrs. Holdens, to make their tide tables, as mentioned in their preface to them. I could not continue any longer to make observations, for want of the command of our dock gate men and gauge rod to take the night tides. Having resigned my place as Dockmaster, this journal ceases by me, William Hutchinson."

These notes contain the only information with respect to the manner in which the observations were made which the books afford. The observations appear to have been carefully conducted, but no precautions are stated to have been taken to ensure the accuracy of the time; and it is difficult to fix whether by solar time is meant *apparent* solar or *mean* solar time: this point ought not to have been left in doubt. This point of uncertainty does not however, in any sensible degree, affect the Tables VI., VII., VIII., and IX., which have reference to the variations of the moon's parallax,

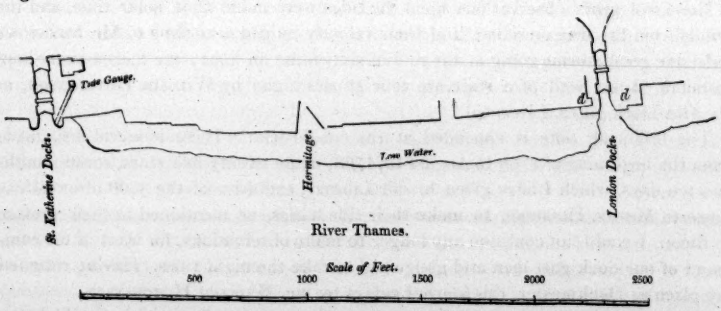
* M. Dessiou has received from the British Association more than £100 for this work.

or those which have reference to the height of high water; but the equation of time is mixed up with the changes in the interval between the moon's transit and the time of high water due to changes in the moon's declination; and any uncertainty with respect to the manner in which the clock has been regulated is therefore much to be regretted.

The plan pursued is the same as that which I adopted with respect to the London Dock observations, and which seems to me to be the only one, in the present state of the subject, which can be resorted to with advantage. If the theory were complete, and the laws or analytical expressions of the phenomena had been made out satisfactorily, it would be possible to proceed at once to determine the constants, which might be done by means of fewer observations, and those might be selected which appeared entitled to the greatest confidence: at present, however, I do not think that this course can be safely pursued.

I trust that this laborious work, which M. Dessiou has accomplished at my instigation, and by the liberal support of the British Association, will not be without utility, and will afford data upon which mathematicians who may hereafter improve the theory of the tides may safely rest their conclusions.

The tides in this port continue to be observed at the London and St. Katherine Docks. These Docks are contiguous, so that the places at which the observations are made are not distant from each other more than 900 yards, as appears from the diagram underneath.



We may therefore, I think, safely conclude, that whatever cause affects the tide at one place will equally affect it at the other; and hence, if we find the difference in the registers of the times and heights of high water much greater than the average difference, suspicion arises that the observation at one or the other place must be erroneous. The observations at the London Docks are made (at the place of the letter *d*) by a person who notes the time when the water has begun to fall, that is, *has made its mark*. Those at the St. Katherine Docks are made by noting upon a slate (ruled for the purpose) the height of the water every minute for a short time

before high water is expected, all which is afterwards copied into a book ruled in the same manner, and the time of high water, with the height, is easily inferred. The height is ascertained by means of a rod or tide-gauge, connected with a float, which is placed in a chamber, into which the water enters through a culvert, so that the ripple or agitation of the water in the river is avoided as much as possible. A clock, carefully regulated, stands close at hand. This plan has been adopted at my suggestion, and, if the observer and the transcriber of the observation do their duty, it does not seem to me to be susceptible of any improvement.

I find by examining the registers of the observations at the London and the St. Katherine Docks, that the tide is on the average about five minutes later there than at the former place, and the difference in height between the lines or zero points, from which the rise is measured, is about five feet. Hence I formed Tables A. and B. by first adding five minutes to the time of high water, and five feet to the height of high water given in the London Dock books, and then comparing the times so altered with those of the St. Katherine Docks. The discrepancies exhibited by these Tables may be attributed to the carelessness of the observers at one or both places, or to the inevitable difficulty of measuring with precision the quantities sought. I next formed Tables C. and D. by adding five minutes to the time of high water given in the St. Katherine Docks register, and five feet to the predicted heights in the British Almanac, in order to compare the observations with the predictions given in the British Almanac, and which are founded upon the Tables, the construction of which I have explained in the Philosophical Transactions, excluding only those observations which, by discordance with the cotemporary observations at the London Docks and with the prediction, appear doubtful. It results from this comparison, that the average error of the predictions of the time of high water contained in the British Almanac is about ten minutes, that is, when the plus and minus errors are not allowed to counteract each other. The average error of Mr. Bulpit's Table is about the same. The tide predictions of Mr. Epps are evidently founded upon the same Tables and the same methods with those in White's Ephemeris, and do not agree quite so well with observation. Those of Mr. Innis are more inaccurate.

When the plus and minus errors are allowed to counteract each other, the average error of the predictions in the British Almanac being, from the observations of the first six months of this year, −9 minutes, leads me to suspect that a change in the establishment has taken place owing to the removal of the old London Bridge. If I am right in this conjecture, it is worthy of remark how sensibly the phenomena of the tides are affected by any slight alteration of local circumstances. Moreover, the height of high water appears to be less by 2 inches than formerly. If the predicted times be increased by 9 minutes and the heights be diminished by 2 inches, the predictions will then agree with observation, nearly as well as the observations at the London and St. Katherine Docks agree with each other.

TABLE A.

Showing a comparison of the observations of the Times of High Water made at the London Docks, increased by five minutes, and those at the St. Katherine Docks. The observations marked with an * appear doubtful.

Date. 1835.	January.			February.			March.			April.			May.			June.		
	London Docks. +5 min.	St. Kath. Docks.	Difference.	London Docks. +5 min.	St. Kath. Docks.	Difference.	London Docks. +5 min.	St. Kath. Docks.	Difference.	London Docks. +5 min.	St. Kath. Docks.	Difference.	London Docks. +5 min.	St. Kath. Docks.	Difference.	London Docks. +5 min.	St. Kath. Docks.	Difference.
	h m	h m	m	h m	h m	m	h m	h m	m	h m	h m	m	h m	h m	m	h m	h m	m
1.	3 5	3 12	− 7	4 20	4 17	+ 3	3 15	3 6	+ 9	3 50	3 52	− 2	3 55	3 49	+ 6	4 45	4 42	+ 3
	3 35	3 47	−12	4 30	4 47	− 17	3 45	3 45	0	4 15	4 16	− 1	4 10	4 5	+ 5	4 10*	4 53	−43
2.	3 55	3 51	+ 4	4 55	4 57	− 2	3 50	3 41	+ 9	4 25	4 26	− 1	4 20	4 22	− 2	5 25	5 25	0
	4 25	4 32	− 7	5 20	5 28	− 8	4 15	4 22	− 7	4 45	4 42	+ 3	4 35	4 36	− 1	5 35	5 43	− 8
3.	4 45	4 38	+ 7	5 15	5 13	+ 2	4 20	4 24	− 4	4 45	4 44	+ 1	4 50	4 46	+ 4	6 25	6 20	+ 5
	5 10	5 9	+ 1	6 5	6 2	+ 3	4 25	4 28	− 3	5 5	5 3	+ 2	5 0	5 8	− 8	6 35	6 34	+ 1
4.	5 25	5 27	− 2	6 5	6 3	+ 2	4 50	4 51	− 1	5 20	5 18	+ 2	5 35	5 26	+ 9	7 5	7 17	−12
	6 5	5 56	+ 9	6 25	6 27	− 2	5 10	5 16	− 6	5 35	5 41	− 6	5 50	5 47	+ 3	7 25	.....	.....
5.	6 20	5 56	+24	6 45	6 37	+ 8	5 20	5 25	− 5	5 50	5 49	+ 1	6 15	6 6	+ 9	8 20	8 12	+ 8
	6 50	6 45	+ 5	7 15	7 17	− 2	5 35	5 37	− 2	6 10	6 12	− 2	6 35	6 37	− 2	8 55	8 57	− 2
6.	7 5	6 47	+18	7 25	7 23	+ 2	5 45	5 41	+ 4	6 35	6 32	+ 3	7 10	7 17	− 7	9 45	9 43	+ 2
	7 30	7 31	− 1	6 15*	8 6*	−111	6 15	6 16	− 1	7 5	7 2	+ 3	7 45	7 56	−11	10 5	10 6	− 1
7.	7 35	7 22	+13	7 50	7 42	+ 8	6 15	6 16	− 1	7 35	7 31	+ 4	8 25	8 20	+ 5	10 40	10 47	− 7
	8 20	8 12	+ 8	8 35	8 45	− 10	6 45	6 46	− 1	8 5	8 1	+ 4	9 5	9 10	− 5	11 20	11 3	+17
8.	8 20	8 11	+ 9	8 45	9 7	− 22	7 15	7 15	0	8 50	9 1	−11	10 10	10 7	+ 3	11 45	11 49	− 4
	9 10	9 8	+ 2	9 35	9 39	− 4	7 15	7 17	− 2	9 55	9 51	+ 4	10 45	10 44	+ 1	12 5	12 3	+ 2
9.	9 20	9 15	+ 5	10 15*	10 47	− 32	7 50	7 45	+ 5	10 35	10 42	− 7	11 15	11 16	− 1	.....	.....	.....
	10 20	10 22	− 2	9 50*	10 25*	− 35	8 55	9 5	−10	11 25	11 28	− 3	11 45	11 50	− 5	12 45	12 43	+ 2
10.	9 15*	10 17	−62	.....	.....	.....	9 5	9 0	+ 5	11 55	12 8	−13	.....	.....	.....	12 55	12 58	− 3
	11 5	11 9	− 4	12 20*	10 42*	+ 98	9 35	10 0	−25	.....	.....	.....	12 15	12 20	− 5	1 35	1 31	+ 4
11.	11 10	11 21	−11	12 35	12 27	+ 8	10 35	10 55	−20	12 20	12 18	+ 2	12 35	12 38	− 3	1 55	1 49	+ 6
	12 5	12 12	− 7	12 55	12 35	+ 20	12 0	11 58	+ 2	1 5	12 57	+ 8	12 55	1 3	− 8	2 15	2 19	− 4
12.	.....	.....	.....	1 20	1 2	+ 18	12 0	12 6	− 6	1 20	1 12	+ 8	1 20	1 15	+ 5	2 35	2 43	− 8
	12 15	12 22	− 7	1 35	1 43	− 8	.....	.....	.....	1 40	1 44	− 4	1 45	1 52	− 7	3 10	3 7	+ 3
13.	1 5	1 2	+ 3	1 55	2 2	− 7	12 50	12 57	− 7	1 55	1 45	+10	2 5	2 3	+ 3	3 25	3 33	− 8
	1 25	1 22	+ 3	2 30	2 28	+ 2	1 20	1 14	+ 6	2 20	2 25	− 5	2 35	2 43	− 8	3 45	3 51	− 6
14.	1 35	1 37	− 2	2 45	2 44	+ 1	1 45	1 47	− 2	2 40	2 35	+ 5	2 55	2 53	+ 2	4 20	4 18	+ 2
	1 55	2 2	− 7	3 15	3 17	− 2	2 5	2 7	− 2	3 5	3 7	− 2	3 20	3 27	− 7	4 35	4 37	− 2
15.	2 20	2 22	− 2	3 35	3 35	0	2 20	2 23	− 3	3 20	3 23	− 3	3 30	3 37	− 7	5 10	5 13	− 3
	2 35	2 36	− 1	3 50	3 48	+ 2	2 35	2 38	− 3	3 45	3 42	+ 3	4 0	4 2	− 2	5 25	5 23	+ 2
16.	2 55	3 1	− 6	4 0	4 3	− 3	2 55	2 57	− 2	4 5	3 57	+ 8	4 25	4 25	0	5 55	6 2	− 7
	3 0	3 1	− 1	4 25	4 33	− 8	3 25	3 27	− 2	4 25	4 22	+ 3	4 55	4 33	+22	6 10	6 8	+ 2
17.	3 30	3 36	− 6	4 45	4 53	− 8	3 45	3 31	+14	4 45	4 38	+ 7	5 15	5 18	− 3	6 50	6 54	− 4
	3 45	3 53	− 8	5 20	5 18	+ 2	4 5	4 16	−11	5 10	5 7	+ 3	5 35	5 32	+ 3	6 55	6 58	− 3
18.	4 10	4 2	+ 8	5 35	5 35	0	4 25	4 19	+ 6	5 25	5 27	− 2	6 10	6 12	− 2	7 50	7 42	+ 8
	4 40	4 46	− 6	6 0	6 12	− 12	4 50	4 56	− 6	5 50	5 57	− 7	6 20	6 27	− 7	7 55	7 55	0
19.	5 0	4 52	+ 8	6 10	6 7	+ 3	5 15	5 7	+ 8	6 10	6 17	− 7	7 10	7 12	− 2	8 50	8 50	0
	5 30	5 33	− 3	6 35	6 37	− 2	5 35	5 30	+ 5	6 40	6 43	− 3	7 20	7 17	+ 3	9 0	8 56	+ 4
20.	5 50	5 48	+ 2	7 5	6 47	+18	5 50	5 41	+ 9	7 25	7 22	+ 3	8 15	8 21	− 6	10 5	9 58	+ 7
	6 10	6 13	− 3	7 30	7 27	+ 3	6 20	6 17	+ 3	7 50	7 50	0	8 40	8 37	+ 3	10 10	10 7	+ 3
21.	6 35	6 33	+ 2	7 45	7 43	+ 2	6 35	6 31	+ 4	8 30	8 37	− 7	9 35	9 33	+ 2	10 40	10 52	−12
	7 10	7 11	− 1	8 25	8 30	− 5	7 5	7 37*	−32	8 55	9 7	−12	9 55	9 47	+ 8	11 5	10 57	+ 8
22.	7 25	7 25	0	8 55	8 52	+ 3	7 25	7 22	+ 3	10 5	10 13	− 8	10 45	10 44	+ 1	11 40	11 52	−12
	7 55	7 57	− 2	9 35	9 28	+ 7	8 10	8 16	− 6	10 30	10 27	+ 3	11 20	10 57	+23	11 55	11 54	+ 1
23.	8 25	8 16	+ 9	10 35	10 35	0	9 10	9 1	+ 9	11 35	11 37	− 2	11 50	11 45	+ 5	.....	.....	.....
	9 5	9 7	− 2	11 5	11 2	+ 3	9 50	9 57	− 7	11 50	11 46	+ 4	11 50	11 59	− 9	12 20	12 22	− 2
24.	9 35	9 29	+ 6	11 25	11 23	+ 2	10 35	10 37	− 2	.....	.....	.....	.....	.....	.....	12 40	12 37	+ 3
	10 10	9 56	+14	.....	.....	.....	11 20	11 22	− 2	12 25	12 26	− 1	12 35	12 36	− 1	1 10	1 3	+ 7
25.	10 35	10 41	− 6	12 15	12 15	0	12 0	12 7	− 7	12 45	12 37	+ 8	12 50	1 16	−26	1 25	1 12	+13
	11 25	11 27	− 2	12 50	12 52	− 2	.....	.....	.....	1 15	.....	.....	1 15	1 33	−18	1 45	1 42	+ 3
26.	.....	.....	.....	1 30	1 33	− 3	12 25	12 27	− 2	1 20	1 17	+ 3	1 20	1 12	+ 8	2 5	2 0	+ 5
	12 10	11 57	+13	1 35	1 32	+ 3	12 55	1 3	− 8	1 45	1 53	− 8	1 45	1 44	+ 1	2 20	2 15	+ 5
27.	12 45	12 42	+ 3	1 50	1 52	− 2	1 10	1 4	+ 6	1 55	1 54	+ 1	1 50	1 53	− 3	2 35	2 35	0
	1 5	1 7	− 2	2 25	2 28	− 3	1 45	1 47	− 2	2 15	2 22	− 7	2 15	2 17	− 2	2 55	2 53	+ 2
28.	1 40	1 31	+ 9	2 35	2 30	+ 5	2 10	1 52	+18	2 35	2 37	− 2	2 25	2 28	− 3	3 5	3 13	− 8
	2 0	2 10	−10	3 0	3 6	− 6	2 35	2 28	− 3	2 50	2 53	− 3	2 50	2 53	− 3	3 35	3 37	− 2
29.	2 25	2 25	0	.....	.....	.....	2 50	2 37	+ 3	3 5	3 8	− 3	3 5	3 4	+ 1	3 55	3 57	− 2
	2 45	2 47	− 2	.....	.....	.....	2 50	2 58	− 8	3 25	3 32	− 7	3 25	3 28	− 3	4 10	4 13	− 3
30.	3 10	3 2	+ 8	.....	.....	.....	3 5	3 3	+ 2	3 30	3 26	+ 4	3 35	3 37	− 2	4 40	4 42	− 2
	3 25	3 32	− 7	.....	.....	.....	3 20	3 22	− 2	3 40	3 35	+ 5	3 55	3 58	− 3	4 55	4 57	− 2
31.	3 45	3 44	+ 1	.....	.....	.....	3 25	3 28	− 3	.....	.....	.....	4 15	4 12	+ 3	.....	.....	.....
	4 5	4 13	− 8	.....	.....	.....	3 40	3 48	− 8	.....	.....	.....	4 25	4 23	+ 2	.....	.....	.....

Table B.

Showing a comparison of the observations of the Heights of High Water made at the London Docks, increased by five feet, and those at the St. Katherine Docks. The observations marked with an * appear doubtful.

Date.	January.					February.					March.					April.					May.					June.				
1835.	London Docks. + 5 ft.		St. Kath. Docks.		Difference.	London Docks. + 5 ft.		St. Kath. Docks.		Difference.	London Docks. + 5 ft.		St. Kath. Docks.		Difference.	London Docks. + 5 ft.		St. Kath. Docks.		Difference.	London Docks. + 5 ft.		St. Kath. Docks.		Difference.	London Docks. + 5 ft.		St. Kath. Docks.		Difference.
	ft.	in.	ft.	in.	in.	ft.	in.	ft.	in.	in.	ft.	in.	ft.	in.	in.	ft.	in.	ft.	in.	in.	ft.	in.	ft.	in.	in.	ft.	in.	ft.	in.	in.
1.	28	0	28	0	0	27	0	27	0	0	27	11	27	9	+ 2	26	9	26	10	− 1	27	4	27	2	+ 2	26	6	26	6	0
	29	6	29	6	0	26	4	26	3	+ 1	27	8	27	8	0	26	7	26	7	0	27	0	26	11	+ 1	25	10	25	10	0
2.	27	4	27	3	+ 1	25	10	25	11	− 1	28	4	28	2	+ 2	26	3	26	3	0	27	0	27	0	0	26	0	25	7	+ 5
	27	2	27	3	− 1	26	11	26	11	0	26	0	25	10	+ 2	26	9	26	3	+ 6	26	10	26	9	+ 1	25	5	25	4	+ 1
3.	26	9	26	9	0	26	8	26	8	0	27	0	26	11	+ 1	27	4	27	3	+ 1	26	9	26	8	+ 1	25	7	25	8	− 1
	26	11	26	10	+ 1	26	11	26	11	0	26	11	26	11	0	26	5	26	5	0	26	1	26	1	0	24	10	24	9	+ 1
4.	26	3	26	2	+ 1	25	9	25	10	− 1	29	1	29	1	0	26	6	26	4	+ 2	25	11	25	9	+ 2	25	5	25	4	+ 1
	26	0	26	0	0	25	11	25	11	0	25	7	25	6	+ 1	25	8	25	8	0	25	1	25	11	−10	24	6	.....	.....	.....
5.	25	10	25	10	0	24	0	24	5	− 5	26	8	26	7	+ 1	25	7	25	7	0	25	3	25	3	0	25	4	23	0*	+28
	25	6	25	10	− 4	23	2*	23	1*	+ 1	26	3	26	4	− 1	24	7	24	4	+ 3	23	3	23	5	− 2	24	5	24	4	+ 1
6.	24	6	24	4	+ 2	24	8	24	9	− 1	22	5	22	3	+ 2	23	11	23	11	0	23	8	23	8	0	25	7	25	7	0
	24	7	24	8	− 1	24	6	24	6	0	25	3	25	3	0	23	3	23	3	0	23	6	23	6	0	25	0	25	1	− 1
7.	24	2	24	2	0	21	2	21	1	+ 1	24	5	24	4	+ 1	23	6	26	4*	−34	24	3	24	2	+ 1	26	0	26	2	− 2
	24	4	24	5	− 1	22	10	22	9	+ 1	22	8	22	7	+ 1	22	8	23	4	− 8	23	11	23	9	+ 2	25	10	25	11	− 1
8.	23	9	25	10*	−25	24	3	24	4	− 1	24	3	24	4	− 1	23	4	23	3	+ 1	24	10	24	10	0	27	0	26	11	+ 1
	23	7	23	8	− 1	23	0	23	0	0	23	2	23	2	0	23	8	23	8	0	24	7	24	9	− 2	26	10	26	6	+ 4
9.	22	6	22	6	0	25	1	25	1	0	21	9	21	7	+ 2	23	11	23	10	+ 1	25	11	26	0	− 1	.....	.....	.....	.....	.....
	23	2	23	1	+ 1	21	5	21	0	+ 5	21	4	21	3	+ 1	24	9	24	9	0	25	6	25	5	+ 1	27	4	27	4	0
10.	25	9	25	8	+ 1	.....	.....	.....	.....	.....	22	0	21	9	+ 3	27	3	27	4	− 1	.....	.....	.....	.....	.....	27	5	27	6	− 1
	23	10	23	10	0	25	0	25	1	− 1	23	7	23	6	+ 1	.....	.....	.....	.....	.....	26	8	26	8	0	27	10	27	11	− 1
11.	24	6	24	5	+ 1	23	7*	25	0	−17	21	2	21	1	+ 1	25	10	26	0	− 2	27	0	26	9	+ 3	28	0	27	10	+ 2
	25	3	25	3	0	24	2	23	8	+ 6	24	10	24	10	0	27	11	28	0	− 1	27	10	28	0	− 2	28	0	28	0	0
12.	.....	.....	.....	.....	.....	24	3*	25	3	−12	25	7	25	8	− 1	26	8	26	7	+ 1	27	4	27	4	0	28	2	28	2	0
	25	4	25	3	+ 1	27	7	27	7	0	.....	.....	.....	.....	.....	27	8	27	7	+ 1	28	5	28	6	− 1	28	1	28	0	+ 1
13.	24	6	24	7	− 1	26	3	26	8	− 5	26	8	26	8	0	27	5	27	1	+ 4	29	0	28	10	+ 2	28	4	28	4	0
	25	5	25	5	0	27	3	27	3	0	27	10	27	10	0	28	7	28	8	− 1	28	8	28	3	+ 5	27	11	27	10	+ 1
14.	26	3	26	3	0	27	6*	27	7	− 1	26	8	26	9	− 1	28	3	28	3	0	30	2	30	3	− 1	28	2	28	2	0
	27	0	27	0	0	27	2	27	1	+ 1	26	3	26	3	0	28	9	28	9	0	29	10	29	10	0	27	3	27	3	0
15.	27	4	27	4	0	27	8	27	3	+ 5	28	3	28	4	− 1	29	1	29	1	0	29	6	29	6	0	27	6	27	7	− 1
	26	10	26	10	+ 1	27	7	27	7	0	28	11	29	0	− 1	29	9	29	8	+ 1	28	9	28	10	− 1	27	4	27	1	+ 3
16.	27	8	27	7	+ 1	27	4	27	4	0	28	5	28	6	− 1	29	11	29	10	+ 1	28	6	28	7	− 1	27	0	26	11	+ 1
	25	6	25	3	+ 3	28	3	27	4	+11	29	1	29	0	+ 1	29	0	29	1	− 1	27	3	28	1	−10	26	3	26	1	+ 2
17.	27	11	28	0	− 1	27	7	27	7	0	28	9	28	9	0	28	10	28	10	0	27	2	27	8	− 6	26	4	26	5	− 1
	28	3	28	0	+ 3	27	9	27	10	− 1	29	0	29	1	− 1	28	0	28	0	0	26	4	26	4	0	25	6	25	6	0
18.	27	11	27	10	+ 1	27	3	27	2	+ 1	29	0	29	0	0	27	4	27	5	− 1	26	11	27	0	− 1	25	4	25	3	+ 1
	27	3	27	4	− 1	25	8	25	7	+ 1	29	1	29	2	- 1	26	1	26	0	+ 1	26	0	25	11	+ 1	24	8	24	2	+ 6
19.	27	7	27	3	+ 4	27	4	27	4	0	28	4	28	4	0	25	7	27	6*	−23	26	1	26	0	+ 1	26	0*	23	11	+25
	27	5	27	6	− 1	25	10	25	9	+ 1	27	7	27	6	+ 1	25	1	25	1	0	24	6	24	5	+ 1	24	7	24	7	0
20.	29	0*	26	11	+25	24	3	24	4	− 1	27	7	27	7	0	25	0	25	1	− 1	25	3	25	2	+ 1	24	0	24	0	0
	27	9	27	6	+ 3	25	11	25	11	0	26	8	26	6	+ 2	24	2	24	1	+ 1	24	3	24	0	+ 3	24	9	24	8	+ 1
21.	25	5	25	5	0	26	0	26	1	− 1	26	7	26	6	+ 1	24	6	24	6	0	24	11	24	10	+ 1	25	0	24	11	+ 1
	25	6	25	7	− 1	25	3	25	3	0	25	7	25	7	0	23	3	23	2	+ 1	24	3	24	3	0	24	0	24	2	− 2
22.	25	10	26	0	− 2	25	0	24	11	+ 1	25	6	25	6	0	25	2	25	1	+ 1	25	1	25	0	+ 1	25	3	25	2	+ 1
	25	9	25	10	− 1	24	1	24	1	0	25	2	25	3	− 1	23	10	23	10	0	24	6	24	7	− 1	24	3*	26	1	−22
23.	24	10	25	0	− 2	20	10*	26	10	−72	24	2	24	4	− 2	23	8*	24	8	−12	25	8	25	9	− 1	.....	.....	.....	.....	.....
	25	2	25	3	− 1	25	4	25	3	+ 1	23	8	23	7	+ 1	24	10	24	9	+ 1	25	3	25	1	+ 2	26	3	26	2	+ 1
24.	24	8	24	5	− 2	26	2	26	2	0	25	0	25	1	− 1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	25	10	25	11	− 1
	26	6	26	6	0	.....	.....	.....	.....	.....	23	9	23	9	0	25	9	25	10	− 1	26	3	26	2	+ 1	26	0	25	11	+ 1
25.	23	11	23	11	0	25	3	25	4	− 1	25	4	25	4	0	25	1	25	1	0	25	0	25	11	−11	24	0	23	9	+ 3
	26	2	26	3	− 1	24	3	24	3	0	.....	.....	.....	.....	.....	26	6	.....	.....	.....	25	10	25	8	+ 2	25	6	25	6	0
26.	.....	.....	.....	.....	0	25	11	24	11	+12	24	6	24	6	0	25	7	25	7	0	25	6	26	6	−12	28	0	27	10	+ 2
	25	4	25	4	0	26	7	27	7	−12	25	11	26	0	− 1	27	0	27	4	− 4	26	9	26	9	0	26	10	26	10	0
27.	26	3	26	4	− 1	26	3	26	3	0	26	3	26	3	0	26	6	26	5	+ 1	27	0	26	10	+ 2	28	6	28	6	0
	26	7	26	8	− 1	26	6	26	7	− 1	27	0	26	11	+ 1	26	8	26	8	0	27	5	27	6	− 1	26	9	27	9	−12
28.	26	7	26	7	0	26	11	26	9	+ 2	27	3	26	6	+ 9	26	7	26	7	0	27	3	27	2	+ 1	27	5	27	3	+ 2
	26	9	26	8	+ 1	28	8	28	9	− 1	27	0	27	2	− 2	27	3	27	2	+ 1	27	3	27	4	− 1	27	1	27	0	+ 1
29.	26	11	26	11	0	.....	.....	.....	.....	.....	27	1	27	0	+ 1	28	0	27	11	+ 1	27	3	27	3	0	27	2	27	1	+ 1
	27	8	27	9	− 1	.....	.....	.....	.....	.....	27	1	27	1	0	28	10	28	11	− 1	27	8	27	7	+ 1	26	9	26	10	− 1
30.	27	3	27	3	0	.....	.....	.....	.....	.....	27	0	27	0	0	28	1	28	1	0	27	4	27	4	0	26	8	26	8	0
	27	10	27	10	0	.....	.....	.....	.....	.....	27	6	27	6	0	27	4	27	5	− 1	27	1	27	1	0	26	6	26	7	− 1
31.	27	1	27	1	0	.....	.....	.....	.....	.....	27	3	27	8	− 5	.....	.....	.....	.....	.....	26	9	26	8	+ 1	.....	.....	.....	.....	.....
	27	6	27	4	+ 2	.....	.....	.....	.....	.....	27	5	27	5	0	.....	.....	.....	.....	.....	26	3	26	3	0	.....	.....	.....	.....	.....

Table C.

Showing a comparison of the observed Times of High Water at the St. Katherine Docks, increased by five minutes, with the predicted Times given in the British Almanac. The observations marked with an * appear doubtful.

Date. 1835.	January.			February.			March.			April.			May.			June.		
	British Alman.	St. Kath. Docks. +5 min.	Error of Pre. diction.	British Alman.	St. Kath. Docks. +5 min.	Error of Pre. diction.	British Alman.	St. Kath. Docks. +5 min.	Error of Pre. diction.	British Alman.	St. Kath. Docks. +5 min.	Error of Pre. diction.	British Alman.	St. Kath. Docks. +5 min.	Error of Pre. diction.	British Alman.	St. Kath. Docks. +5 min.	Error of Pre. diction.
	h m	h m	m	h m	h m	m	h m	h m	m	h m	h m	m	h m	h m	m	h m	h m	m
1.	3 14	3 17	− 3	4 20	4 22	− 2	3 24	3 11	+13	3 56	3 57	− 1	3 55	3 54	+ 1	4 41	4 47	− 6
	3 33	3 52	−19	4 38	4 52	−14	3 42	3 50	− 8	4 11	4 21	−10	4 11	4 10	+ 1	5 1	4 58	+ 3
2.	3 56	3 56	0	4 55	5 2	− 7	3 58	3 46	+12	4 23	4 31	− 8	4 25	4 27	− 2	5 22	5 30	− 8
	4 20	4 37	−17	5 12	5 33	−21	4 11	4 27	−16	4 36	4 47	−11	4 40	4 41	− 1	5 46	5 48	− 2
3.	4 40	4 43	− 3	5 30	5 18	+12	4 26	4 29	− 3	4 50	4 49	+ 1	4 56	4 51	+ 5	6 13	6 25	−12
	5 1	5 14	−13	5 45	6 7	−22	4 41	4 33	+ 8	5 3	5 8	− 5	5 14	5 13	+ 1	6 40	6 39	+ 1
4.	5 20	5 32	−12	6 2	6 8	− 6	4 56	4 56	0	5 20	5 23	− 3	5 33	5 31	+ 2	7 6	7 22	−16
	5 43	6 1	−18	6 20	6 32	−12	5 9	5 21	−12	5 37	5 46	− 9	5 55	5 52	+ 3	7 39	.....	.....
5.	6 2	6 1	+ 1	6 36	6 42	− 6	5 25	5 30	− 5	5 56	5 54	+ 2	6 20	6 11	+ 9	8 14	8 17	− 3
	6 25	6 50	−25	6 55	7 22	−27	5 42	5 42	0	6 14	6 17	− 3	6 46	6 42	+ 4	8 51	9 2	−11
6.	6 47	6 52	− 5	7 14	7 28	−14	5 58	5 46	+12	6 36	6 37	− 1	7 18	7 22	− 4	9 27	9 48	−21
	7 11	7 36	−25	7 35	8 11*		6 13	6 21	− 8	7 4	7 7	− 3	7 55	8 1	− 6	9 59	10 11	−12
7.	7 34	7 27	+ 7	8 0	7 47	+13	6 32	6 21	+11	7 33	7 36	− 3	8 36	8 25	+11	10 30	10 52	−22
	7 55	8 17	−22	8 25	8 50	−25	6 50	6 51	− 1	8 14	8 6	+ 8	9 18	9 15	+ 3	11 3	11 8	− 5
8.	8 18	8 16	+ 2	9 3	9 12	− 9	7 10	7 20	−10	9 0	9 6	− 6	9 59	10 12	−13	11 34	11 54	−20
	8 46	9 13	−27	9 39	9 44	− 5	7 36	7 22	+14	9 45	9 56	−11	10 40	10 49	− 9	12 4	12 8	− 4
9.	9 15	9 20	− 5	10 17	10 52	−35	8 4	7 50	+14	10 30	10 47	−17	11 15	11 21	− 6	.....	.....	.....
	9 46	10 37	−41	11 1	10 30*		8 49	9 10	−21	11 12	11 33	−21	11 48	11 55	− 7	12 31	12 48	−17
10.	10 19	10 22	− 3	.....	.....	.....	9 32	9 5	+27	11 45	12 13	−28	.....	.....	.....	12 57	1 3	− 6
	10 53	11 14	−21	11 36	10 47*		10 20	10 5	+15	.....	.....	.....	12 15	12 25	−10	1 21	1 36	−15
11.	11 24	11 26	− 2	12 8	12 32	−24	11 4	11 0	+ 4	12 15	12 23	− 8	12 37	12 43	− 6	1 46	1 54	− 8
	11 50	12 17	−27	12 28	12 40	−12	11 39	12 3	−24	12 43	1 2	−19	12 59	1 8	− 9	2 10	2 24	−14
12.	.....	.....	.....	1 8	1 7	+ 1	12 4	12 11	− 7	1 10	1 17	− 7	1 20	1 20	0	2 36	2 48	−12
	12 18	12 27	− 9	1 33	1 48	−15	.....	.....	.....	1 35	1 49	−14	1 43	1 57	−14	3 2	3 12	−10
13.	12 42	1 7	−25	1 56	2 7	−11	12 43	1 2	−19	1 53	1 50	+ 3	2 5	2 8	− 3	3 27	3 38	−11
	1 6	1 27	−21	2 21	2 33	−12	1 11	1 19	− 8	2 11	2 30	−19	2 27	2 48	−21	3 53	3 56	− 3
14.	1 29	1 42	−13	2 41	2 49	− 8	1 34	1 52	−18	2 31	2 40	− 9	2 51	2 58	− 7	4 19	4 23	− 4
	1 52	2 7	−15	3 1	3 22	−21	1 57	2 12	−15	2 53	3 12	−19	3 13	3 32	−19	4 37	4 42	− 5
15.	2 13	2 27	−14	3 21	3 40	−19	2 18	2 28	−10	3 16	3 28	−12	3 37	3 42	− 5	5 0	5 18	−18
	2 33	2 41	− 8	3 40	3 53	−13	2 38	2 43	− 5	3 38	3 47	− 9	4 1	4 7	− 6	5 23	5 28	− 5
16.	2 54	3 6	−12	4 0	4 8	− 8	3 0	3 2	− 2	3 58	4 2	− 4	4 24	4 30	− 6	5 44	6 7	−23
	3 9	3 6	+ 3	4 22	4 38	−16	3 20	3 32	−12	4 20	4 27	− 7	4 46	4 38	+ 8	6 9	6 13	− 4
17.	3 33	3 41	− 8	4 41	4 58	−17	3 39	3 36	+ 3	4 39	4 43	− 4	5 11	5 23	−12	6 36	6 59	−23
	3 53	3 58	− 5	5 1	5 23	−22	3 58	4 21	−23	5 1	5 12	−11	5 36	5 37	− 1	7 3	7 3	0
18.	4 16	4 7	+ 9	5 24	5 30	− 6	4 20	4 24	− 4	5 22	5 32	−10	6 2	6 17	−15	7 28	7 47	−19
	4 38	4 51	−13	5 46	6 17	−31	4 39	5 1	−22	5 46	6 2	−16	6 27	6 32	− 5	8 1	8 0	+ 1
19.	5 1	4 57	+ 4	6 7	6 12	− 5	5 0	5 12	−12	6 8	6 22	−14	6 55	7 17	−22	8 32	8 55	−23
	5 24	5 38	−14	6 30	6 42	−12	5 22	5 35	−13	6 35	6 48	−13	7 28	7 22	+ 6	9 1	9 1	0
20.	5 51	5 53	− 2	6 53	6 52	+ 1	5 44	5 46	− 2	7 4	7 27	−23	8 1	8 26	−25	9 31	10 3	−32
	6 17	6 18	− 1	7 15	7 32	−17	6 5	6 22	−17	7 38	7 55	−17	8 41	8 42	− 1	10 1	10 12	−11
21.	6 39	6 38	+ 1	7 40	7 48	− 8	6 28	6 36	− 8	8 25	8 42	−17	9 20	9 38	−18	10 30	10 57	−27
	7 1	7 16	−15	8 13	8 35	−22	6 52	7 42*		9 12	9 12	0	9 59	9 52	+ 7	11 0	11 2	− 2
22.	7 25	7 30	− 5	8 54	8 57	− 3	7 19	7 27	− 8	9 58	10 18	−20	10 38	10 49	−11	11 31	11 57	−26
	7 48	8 2	−14	9 41	9 33	+ 8	7 52	8 21	−29	10 42	10 32	+10	11 15	11 2	+13	11 56	11 59	− 3
23.	8 18	8 21	− 3	10 28	10 40	−12	8 39	9 6	−27	11 21	11 42	−21	11 44	11 50	− 6	.....	.....	.....
	8 49	9 12	−23	11 11	11 7	+ 4	9 27	10 2	−35	11 55	11 51	+ 4	12 6	12 4	+ 2	12 18	12 27	− 9
24.	9 23	9 34	−11	11 50	11 28	+22	10 17	10 42	−25	.....	.....	.....	.....	.....	.....	12 41	12 42	− 1
	10 1	10 1	0	.....	.....	.....	11 5	11 27	−22	12 22	12 31	− 9	12 25	12 41	−16	1 3	1 8	− 5
25.	10 43	10 46	− 3	12 25	12 20	+ 5	11 45	12 12	−27	12 46	12 42	+ 4	12 44	1 21	−37	1 23	1 17	+ 6
	11 21	11 32	−11	12 57	12 57	0	.....	.....	.....	1 8	.....	.....	1 1	1 38	−37	1 42	1 47	− 5
26.	.....	.....	.....	1 25	1 38	−13	12 16	12 32	−16	1 28	1 22	+ 6	1 20	1 17	+ 3	2 0	2 5	− 5
	11 58	12 2	− 4	1 52	1 37	+15	12 44	1 8	−24	1 44	1 58	−14	1 37	1 49	−12	2 18	2 20	− 2
27.	12 31	12 47	−16	2 10	1 57	+13	1 10	1 9	+ 1	1 55	1 59	− 4	1 52	1 58	− 6	2 38	2 40	− 2
	1 5	1 12	− 7	2 31	2 33	− 2	1 33	1 52	−19	2 10	2 27	−17	2 8	2 22	−14	2 57	2 58	− 1
28.	1 31	1 36	− 5	2 49	2 35	+14	1 50	1 57	− 7	2 25	2 42	−17	2 23	2 33	−10	3 15	3 18	− 3
	1 58	2 15	−17	3 7	3 11	− 4	2 8	2 33	−25	2 40	2 58	−18	2 40	2 58	−18	3 33	3 42	− 9
29.	2 19	2 30	−11	.....	.....	.....	2 27	2 32	− 5	2 54	3 13	−19	2 57	3 9	−12	3 52	4 2	−10
	2 42	2 52	−10	.....	.....	.....	2 44	3 3	−19	3 8	3 37	−29	3 14	3 33	−19	4 12	4 18	− 6
30.	3 4	3 7	− 3	.....	.....	.....	2 59	3 8	− 9	3 24	3 31	− 7	3 30	3 42	−12	4 32	4 47	−15
	3 25	3 37	−12	.....	.....	.....	3 13	3 27	−14	3 39	3 40	− 1	3 47	4 3	−16	4 53	5 2	− 9
31.	3 43	3 49	− 6	.....	.....	.....	3 27	3 33	− 6	.....	.....	.....	4 7	4 17	−10	.....	.....	.....
	4 2	4 18	−16	.....	.....	.....	3 43	3 53	−10	.....	.....	.....	4 26	4 28	− 2	.....	.....	.....

Table D.

Showing a comparison of the observed Heights of High Water at the St. Katherine Docks, with the predicted Heights given in the British Almanac, increased by five feet. The observations marked with an * appear doubtful.

Date. 1835.	January.			February.			March.			April.			May.			June.		
	British Alman. + 5 ft.	St. Kath. Docks.	Error of Pre-diction.	British Alman. + 5 ft.	St. Kath. Docks.	Error of Pre-diction.	British Alman. + 5 ft.	St. Kath. Docks.	Error of Pre-diction.	British Alman. + 5 ft.	St. Kath. Docks.	Error of Pre-diction.	British Alman. + 5 ft.	St. Kath. Docks.	Error of Pre-diction.	British Alman. + 5 ft.	St. Kath. Docks.	Error of Pre-diction.
	ft. in.	ft. in.	in.	ft. in.	ft. in.	in.	ft. in.	ft. in.	in.	ft. in.	ft. in.	in.	ft. in.	ft. in.	in.	ft. in.	ft. in.	in.
1.	27 10	28 0	− 2	27 5	27 0	+ 5	27 6	27 9	− 3	27 3	26 10	+ 5	27 2	27 2	0	26 11	26 6	+ 5
	27 9	29 6	−21	27 3	26 3	+12	27 6	27 8	− 2	27 2	26 7	+ 7	27 1	26 11	+ 2	26 9	25 10	+11
2.	27 8	27 3	+ 5	27 1	25 11	+14	27 6	28 2	− 8	27 0	26 3	+ 9	26 11	27 0	− 1	26 4	25 7	+ 9
	27 6	27 3	+ 3	26 10	26 11	− 1	27 5	25 10	+19	26 10	26 3	+ 7	26 9	26 9	0	26 2	25 4	+10
3.	27 3	26 9	+ 6	26 6	26 8	− 2	27 2	26 11	+ 3	26 8	27 3	− 7	26 6	26 8	− 2	25 11	25 8	+ 3
	27 0	26 10	+ 2	26 3	26 11	− 8	27 0	26 11	+ 1	26 6	26 5	+ 1	26 3	26 1	+ 2	25 8	24 9	+11
4.	26 7	26 2	+ 5	25 11	25 9	+ 2	26 10	29 1	−27	26 3	26 4	− 1	26 0	25 9	+ 3	25 5	25 4	+ 1
	26 2	26 0	+ 2	25 7	25 11	− 4	26 8	25 6	+14	25 11	25 8	+ 3	25 8	25 11	− 3	25 2	.....	.....
5.	25 11	25 10	+ 1	25 4	24 5	+11	26 5	26 7	− 2	25 7	25 7	0	25 4	25 3	+ 1	25 2	23 0*	
	25 7	25 10	− 3	25 1	23 1*		26 2	26 4	− 2	25 3	24 4	+11	25 0	23 5	+19	25 3	24 4	+11
6.	25 3	24 4	+11	24 9	24 9	0	25 10	22 3	+43	24 11	23 11	+12	24 9	23 8	+13	25 5	25 7	− 2
	25 0	24 8	+ 4	24 5	24 6	− 1	25 5	25 3	+ 2	24 7	23 3	+16	24 8	23 6	+14	25 8	25 1	+ 7
7.	24 8	24 2	+ 6	24 2	21 1	+37	25 3	24 4	+11	24 4	26 4*		24 8	24 2	+ 6	25 10	26 2	− 4
	24 5	24 5	0	23 11	22 9	+14	24 11	22 7	+28	24 3	23 4	+11	24 10	23 9	+13	26 1	25 11	+ 2
8.	24 2	25 10*		23 10	24 4	− 6	24 7	24 4	+ 3	24 3	23 3	+12	25 3	24 10	+ 5	26 5	26 11	− 6
	24 0	23 8	+ 4	23 10	23 0	+10	24 3	23 2	+13	24 7	23 8	+11	25 9	24 9	+12	26 9	26 6	+ 3
9.	23 11	22 6	+17	24 1	25 1	−12	24 1	21 7	+30	25 1	23 10	+15	26 3	26 0	+ 3	.....	.....	.....
	23 11	23 1	+10	24 7	21 0	+43	23 11	21 3	+32	25 8	24 9	+11	26 9	25 5	+16	27 0	27 4	− 4
10.	24 0	25 8	−20	.....	.....	.....	24 1	21 9	+28	26 2	27 4	−14	.....	.....	.....	27 4	27 6	− 2
	24 3	23 10	+ 5	25 1	25 1	0	24 6	23 6	+12	.....	.....	.....	27 0	26 8	+ 4	27 7	27 11	− 4
11.	24 7	24 5	+ 2	25 6	25 0	+ 6	24 11	21 1	+46	26 8	26 0	+ 8	27 4	26 9	+ 7	27 10	27 10	0
	25 1	25 3	− 2	26 0	23 8	+28	25 6	24 10	+ 8	27 2	28 0	−10	27 7	28 0	− 5	28 0	28 0	0
12.	.....	.....	.....	26 7	25 3	+16	26 0	25 8	+ 4	27 8	26 7	+13	27 9	27 4	+ 5	28 1	28 2	− 1
	25 3	25 3	0	27 0	27 7	− 7	.....	.....	.....	27 11	27 7	+ 4	28 0	28 6	− 6	28 2	28 0	+ 2
13.	25 10	24 7	+15	27 5	26 8	+ 9	26 8	26 8	0	28 1	27 1	+12	28 2	28 10	− 8	28 2	28 4	− 2
	26 4	25 5	+11	27 9	27 3	+ 6	27 2	27 10	− 8	28 3	28 8	− 5	28 3	28 3	0	28 1	27 10	+ 3
14.	26 8	26 3	+ 5	27 11	27 7	+ 4	27 6	26 9	+ 9	28 4	28 3	+ 1	28 4	30 3	−23	27 10	28 2	− 4
	27 0	27 0	0	28 1	27 1	+12	27 10	26 3	+19	28 5	28 9	− 4	28 4	29 10	−18	27 7	27 3	+ 4
15.	27 5	27 4	+ 1	28 3	27 3	+12	28 2	28 4	− 2	28 6	29 1	− 7	28 4	29 6	−14	27 2	27 7	− 5
	27 7	26 10	+ 9	28 4	27 7	+ 9	28 4	29 0	− 8	28 6	29 8	−14	28 2	28 10	− 8	26 9	27 1	− 4
16.	27 9	27 7	+ 2	28 5	27 4	+13	28 5	28 6	− 1	28 5	29 10	−17	27 11	28 7	− 8	26 4	26 11	− 7
	27 10	25 3	+31	28 4	27 4	+12	28 6	29 0	− 6	28 3	29 1	−10	27 5	28 1	− 8	25 11	26 1	− 2
17.	28 0	28 0	0	28 2	27 7	+ 7	28 6	28 9	− 3	27 11	28 10	−11	27 0	27 8	− 8	25 6	26 5	−11
	28 0	28 0	0	28 0	27 10	+ 2	28 6	29 1	− 7	27 6	28 0	− 6	26 6	26 4	+ 2	25 1	25 6	− 5
18.	28 0	27 10	+ 2	27 9	27 2	+ 7	28 4	29 0	− 8	27 0	27 5	− 5	26 1	27 0	−11	24 9	25 3	− 6
	27 11	27 4	+ 7	27 5	25 7	+22	28 2	29 2	−12	26 6	26 0	+ 6	25 6	25 11	− 5	24 6	24 2	+ 4
19.	27 9	27 3	+ 6	27 0	27 4	− 4	27 11	28 4	− 5	25 11	27 6*		25 0	26 0	−12	24 3	23 11	+ 4
	27 6	27 6	0	26 7	25 9	+10	27 7	27 6	+ 1	25 3	25 1	+ 2	24 7	24 5	+ 2	24 2	24 7	− 5
20.	27 3	26 11	+ 4	26 0	24 4	+20	27 1	27 7	− 6	24 9	25 1	− 4	24 3	25 2	−11	24 1	24 0	+ 1
	27 0	27 6	− 6	25 5	25 11	− 6	26 6	26 6	0	24 4	24 1	+ 3	24 2	24 0	+ 2	24 1	24 8	− 7
21.	26 8	25 5	+15	25 0	26 1	−11	25 11	26 6	− 7	24 2	24 6	− 4	24 2	24 10	− 8	24 2	24 11	− 9
	26 3	25 7	+ 8	24 7	25 3	− 8	25 4	25 7	− 3	24 1	23 2	+11	24 4	24 3	+ 1	24 4	24 2	+ 2
22.	25 10	26 0	− 2	24 4	24 11	− 7	24 10	25 6	− 8	24 3	25 1	−10	24 7	25 0	− 5	24 7	25 2	− 7
	25 5	25 10	− 5	24 4	24 1	+ 3	24 5	25 3	−10	24 6	23 10	+ 8	24 11	24 7	+ 4	24 10	26 1	−15
23.	25 1	25 0	+ 1	24 7	26 10	−27	24 2	24 4	− 2	24 11	24 8	+ 3	25 1	25 9	− 8	.....	.....	.....
	24 9	25 3	− 6	24 11	25 3	− 4	24 2	23 7	+ 7	25 3	24 9	+ 6	25 3	25 1	+ 2	25 2	26 2	−12
24.	24 8	24 5	+ 3	25 4	26 2	−10	24 5	25 1	− 8	.....	.....	.....	.....	.....	.....	25 5	25 11	− 6
	24 9	26 6	−21	.....	.....	.....	24 9	23 9	+12	25 7	25 10	− 3	25 6	26 2	− 8	25 10	25 11	− 1
25.	25 0	23 11	+13	25 9	25 4	+ 5	25 2	25 4	− 2	25 11	25 1	+10	25 8	25 11	− 3	26 3	23 9	+30
	25 4	26 3	−11	26 3	24 3	+24	.....	.....	.....	26 3	.....	.....	26 0	25 8	+ 4	26 6	25 6	+12
26.	.....	.....	.....	26 7	24 11	+20	25 6	24 6	+12	26 7	25 7	+12	26 3	26 6	− 3	26 10	27 10	−12
	25 9	25 4	+ 5	26 10	27 7	− 9	25 10	26 0	− 2	26 9	27 4	− 7	26 6	26 9	− 3	27 1	26 10	+ 3
27.	26 2	26 4	− 2	26 1	26 3	− 2	26 1	26 3	− 2	26 10	26 5	+ 5	26 8	26 10	− 2	27 4	28 6	−14
	27 6	27 6	8	27 4	26 7	+ 9	26 7	26 11	− 4	26 11	26 8	+ 3	26 11	27 6	− 7	27 5	27 9	− 4
28.	26 11	26 7	+ 4	27 6	26 9	+ 9	26 10	26 6	+ 4	27 1	26 7	+ 6	27 1	27 2	− 1	27 6	27 3	+ 3
	27 2	26 8	+ 6	27 6	28 9	−15	27 1	27 2	− 1	27 2	27 2	0	27 2	27 4	− 2	27 7	27 0	+ 7
29.	27 5	26 11	+ 6	.....	.....	.....	27 4	27 0	+ 4	27 3	27 11	− 8	27 3	27 3	0	27 6	27 1	+ 5
	27 7	27 9	− 2	.....	.....	.....	27 5	27 1	+ 4	27 3	28 11	−20	27 4	27 7	− 3	27 6	26 10	+ 8
30.	27 8	27 3	+ 5	.....	.....	.....	27 5	27 0	+ 5	27 3	28 1	−10	27 4	27 4	0	27 5	26 8	+ 9
	27 8	27 10	− 2	.....	.....	.....	27 5	27 6	− 1	27 3	27 5	− 2	27 3	27 1	+ 2	27 3	26 7	+ 8
31.	27 7	27 1	+ 6	.....	.....	.....	27 4	27 8	− 4	.....	.....	.....	27 2	26 8	+ 6	.....	.....	.....
	27 6	27 4	+ 2	.....	.....	.....	27 3	27 5	− 2	.....	.....	.....	27 1	26 3	+10	.....	.....	.....

Table I.

Showing the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Height of High Water at the Liverpool Old Docks (as recorded by Mr. Hutchinson), corresponding to the Apparent Solar Time of the Moon's Transit, in each month of the year. (If Mr. Hutchinson's clock was regulated according to *mean* solar time, the interval must be *diminished* by the equation of time given at foot of each month.)

January.

Number of Observations.	Moon's Transit.	Interval.	Height of Tide.	Mean of Moon's Decl.
	h m	h m	ft. in.	°
90	31·2	11 13·3	17 5·6	18
97	1 31·6	10 59·1	17 9·0	15
93	2 31·3	10 46·8	17 6·1	10
103	3 30·1	10 37·1	16 1·0	5
100	4 28·5	10 31·2	15 2·2	5
105	5 30·6	10 33·9	13 8·3	8
96	6 29·7	10 49·2	12 7·3	14
95	7 30·5	11 16·3	12 4·3	19
93	8 30·8	11 38·1	13 6·7	19
84	9 30·6	11 45·1	14 11·5	23
89	10 31·1	11 38·4	16 0·0	22
84	11 31·6	11 34·1	16 8·9	22
Equat. of Time *to be added to app. time*...		+10	...	...

February.

Number of Observations.	Moon's Transit.	Interval.	Height of Tide.	Mean of Moon's Decl.
	h m	h m	ft. in.	°
89	31·9	11 17·9	18 0·6	10
92	1 31·4	11 8·0	18 0·5	5
90	2 30·9	10 49·4	17 8·4	5
90	3 29·3	10 37·4	16 8·9	8
92	4 29·1	10 27·3	15 2·5	14
86	5 29·2	10 26·2	13 4·7	18
86	6 29·7	10 37·8	11 11.5	21
84	7 30·8	11 8·3	11 9·3	21
79	8 30·4	11 37·6	12 9·4	23
82	9 29·8	11 51·1	14 5·7	22
79	10 31·1	11 43·8	15 11·6	19
84	11 30·2	11 31·5	17 4·8	15
...	...	+15	...	...

March.

Number of Observations.	Moon's Transit.	Interval.	Height of Tide.	Mean of Moon's Decl.
	h m	h m	ft. in.	°
105	30·0	11 19·1	18 4·7	5
99	1 30·9	11 3·7	18 5·9	8
101	2 31·9	10 49·0	17 7·3	13
92	3 31·2	10 33·0	16 3·4	16
89	4 30·2	10 20·3	14 5·8	21
89	5 30·4	10 16·2	13 0·0	22
88	6 31·6	10 30·5	11 4·6	22
85	7 30·4	11 5·9	11 3·7	22
94	8 31·0	11 41·3	12 8·5	20
98	9 31·8	11 50·6	14 8·1	15
97	10 31·2	11 44·8	16 6·9	10
92	11 29·7	11 33·5	17 8·1	6
...	...	+9	...	...

April.

90	29·9	11 19·4	18 0·1	12
91	1 30·5	11 1·0	17 10·6	17
87	2 30·0	10 43·4	17 0·1	20
87	3 30·9	10 30·2	15 11·6	22
87	4 31·0	10 14·0	14 5·1	23
85	5 30·7	10 12·9	12 10·6	22
90	6 30·5	10 31·9	11 5·2	20
92	7 30·4	11 14·5	11 8·6	16
93	8 29·6	11 43·9	13 3·2	11
96	9 28·4	11 54·2	15 0·3	6
104	10 29·1	11 48·3	16 7·2	5
94	11 29·1	11 36·1	17 7·2	7
Equat. of Time *to be added to app. time*...		0	...	...

May.

86	29·1	11 16·5	17 4·1	20
89	1 30·1	10 57·9	17 1·9	22
85	2 31·4	10 38·3	16 6·6	23
82	3 30·3	10 25·1	15 9·1	22
93	4 29·2	10 16·0	14 6·0	20
97	5 30·4	10 18·8	13 3·9	16
99	6 29·3	10 41·6	12 4·2	12
105	7 29·7	11 20·6	12 7·0	7
103	8 30·0	11 46·9	13 9·0	5
102	9 30·5	11 52·6	15 11·2	7
97	10 31·2	11 46·8	16 3·2	12
89	11 30·0	11 31·2	17 0·1	17
...	...	−4	...	...

June.

79	30·3	11 13·4	16 8·8	23
85	1 30·0	10 55·5	16 10·1	22
85	2 30·0	10 39·8	16 7·9	20
92	3 30·0	10 29·6	15 9·8	16
98	4 30·3	10 24·9	14 8·3	11
96	5 29·6	10 31·5	13 9·0	6
107	6 29·6	10 52·8	13 0·8	5
98	7 30·4	11 24·7	13 1·1	8
97	8 30·2	11 44·0	13 10·4	12
92	9 31·1	11 49·1	14 11·4	17
85	10 30·3	11 41·8	15 11·0	20
83	11 31·1	11 28·7	16 7·0	22
...	...	0	...	...

July.

88	32·0	11 13·1	17 1·2	19
89	1 31.1	10 57·6	17 1·8	16
100	2 30·6	10 45·2	16 10·1	11
101	3 31·5	10 37·4	16 3·4	6
101	4 31·1	10 33·1	14 11·3	5
99	5 29·7	10 34·2	13 10·0	8
101	6 29·5	10 51·5	12 10·6	13
96	7 30·4	11 12·3	12 8·8	18
91	8 30·7	11 39·2	13 4·9	21
86	9 29·7	11 48·5	14 7·8	22
91	10 30·5	11 39·5	15 7·3	23
89	11 32·6	11 26·7	16 6·5	22
Equat. of Time *to be added to app. time*...		+5	...	...

August.

95	31·2	11 17·2	17 8·4	11
99	1 29·5	11 4·6	17 11·6	6
105	2 29·0	10 51·8	17 4·6	5
102	3 29·3	10 35·5	16 5·5	7
97	4 29·6	10 30·2	15 0·4	13
96	5 30·0	10 28·7	13 5·6	17
89	6 29·7	10 38·3	12 0·0	21
85	7 29·2	11 8·2	11 9·5	22
90	8 29·8	11 37·4	12 9·9	25
86	9 30·8	11 47·0	14 4·3	22
91	10 30·9	11 42·3	15 10·3	19
91	11 30·4	11 30·1	17 0·0	16
.....	...	+4	...	...

September.

96	31·1	11 20·1	18 3·8	4
96	1 31·3	11 2·6	18 4·8	7
97	2 30·4	10 48·7	17 10·8	12
93	3 30·3	10 34·9	16 6·0	17
88	4 30·2	10 21·3	14 11·3	20
82	5 29·0	10 16·9	13 2·7	22
92	6 29·7	10 32·1	11 7·5	23
82	7 30·7	11 5·2	11 9·3	22
89	8 30·0	11 39·3	12 10·3	20
92	9 31·4	11 50·5	14 9·9	16
91	10 30·7	11 46·3	16 4·9	11
101	11 32·2	11 34·8	17 8·5	6
...	...	−5	...	...

October.

93	29·1	11 19·3	18 6·3	11
95	1 29·3	11 1·9	18 3·5	16
89	2 28·1	10 42·9	17 7·7	20
93	3 29·1	10 26·9	16 6·0	22
95	4 30·8	10 14·6	14 9·0	23
86	5 31·3	10 12·2	13 1·3	22
91	6 31·2	10 29·4	11 8·2	20
97	7 31·2	11 11·8	11 11·6	17
97	8 31·6	11 46·0	13 4·9	13
97	9 30·9	11 54·1	15 2·0	7
98	10 28·7	11 48·9	16 9·7	4
96	11 29·8	11 35·3	17 11·1	7
Equat. of Time *to be added to app. time*...		−14	...	...

November.

85	32·6	11 17·8	17 11·6	20
81	1 31·5	10 58·2	17 8·8	22
83	2 30·5	10 39·0	17 0·0	23
84	3 29·6	10 24·2	16 0·0	22
94	4 30·0	10 14·7	14 6·0	20
89	5 32·1	10 17·3	13 3·6	16
99	6 30·0	10 40·4	12 3·3	13
99	7 30·1	11 21·3	12 7·5	7
99	8 29·4	11 47·6	13 11·3	5
99	9 29·5	11 53·8	15 7·3	6
93	10 29·0	11 46·8	16 8·6	12
96	11 30·8	11 32·7	17 6·1	17
...	...	−15	...	...

December.

80	31·3	11 12·6	17 3·1	23
85	1 30·4	10 54·7	17 3·4	21
86	2 29·9	10 40·8	16 9·6	19
97	3 29·3	10 28·8	15 10·9	16
102	4 31·1	10 23·9	14 11·3	11
103	5 30·9	10 30·7	13 9·7	8
109	6 31·5	10 53·0	13 0·6	5
100	7 31·2	11 24·0	13 2·7	7
100	8 29·1	11 45·5	14 0·8	12
90	9 28·5	11 48·3	15 3·9	17
95	10 28·9	11 42·5	16 4·6	20
84	11 30·6	11 27·6	17 1·7	21
...	...	−4	...	...

The argument of all the Tables is the time of the Moon's transit at Greenwich, taken immediately from the Nautical Almanac, which only amounts to neglecting the Moon's proper motion during twelve minutes.

TABLE II. (Interpolated from Table I.)

Showing the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water at Liverpool Old Dock, for each month in the year.

Moon's Transit.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Mean.
h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
30	11 13·7	11 18·3	11 19·1	11 19·4	11 16·3	11 13·4	11 13·5	11 17·5	11 20·4	11 19·1	11 18·4	11 12·9	11 17·1
1 30	10 59·5	11 8·2	11 3·9	11 1·1	10 57·9	10 55·5	10 57·8	11 4·5	11 3·0	11 1·7	10 58·7	10 54·8	11 0·7
2 30	10 47·0	10 49·7	10 49·4	10 43·4	10 38·6	10 39·8	10 45·2	10 51·6	10 48·8	10 42·3	10 39·1	10 40·8	10 43·9
3 30	10 37·1	10 37·3	10 33·3	10 30·4	10 25·1	10 29·6	10 37·6	10 35·4	10 34·0	10 26·7	10 24·1	10 28·7	10 31·5
4 30	10 31·1	10 27·3	10 20·3	10 14·2	10 16·0	10 24·9	10 33·1	10 30·2	10 21·3	10 14·7	10 14·7	10 23·9	10 22·7
5 30	10 33·8	10 26·3	10 16·2	10 12·8	10 18·8	10 31·6	10 34·2	10 28·7	10 16·9	10 12·2	10 17·1	10 30·6	10 23·3
6 30	10 49·3	10 37·9	10 30·2	10 31·8	10 41·9	10 52·9	10 51·6	10 38·4	10 32·1	10 29·1	10 40·4	10 52·5	10 41·0
7 30	11 16·1	11 8·0	11 5·8	11 8·5	11 20·6	11 24·6	11 12·2	11 8·6	11 4·8	11 11·0	11 21·3	11 23·4	11 14·4
8 30	11 37·8	11 37·4	11 40·7	11 44·0	11 46·9	11 44·0	11 38·9	11 37·4	11 39·3	11 45·1	11 47·9	11 45·7	11 42·2
9 30	11 45·0	11 51·0	11 50·3	11 54·3	11 52·5	11 49·2	11 48·5	11 46·9	11 50·3	11 54·0	11 53·8	11 48·2	11 50·4
10 30	11 38·5	11 44·0	11 44·9	11 48·2	11 46·9	11 41·8	11 39·6	11 42·4	11 46·4	11 48·7	11 46·7	11 42·2	11 44·2
11 30	11 34·2	11 31·5	11 33·4	11 36·0	11 31·2	11 28·9	11 27·2	11 30·1	11 35·2	11 35·3	11 39·9	11 27·7	11 32·0

TABLE III. (Interpolated from Table I.)

Showing the Height of High Water at Liverpool Old Docks, corresponding to the Apparent Solar Time of the Moon's Transit, in each month of the year.

Moon's Transit.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Mean.
h m	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
30	17·47	18·05	18·38	18·01	17·33	16·73	17·08	17·68	18·30	18·52	17·95	17·25	17·73
1 30	17·74	18·04	18·49	17·88	17·15	16·84	17·14	17·96	18·39	18·28	17·73	17·28	17·78
2 30	17·52	17·69	17·63	17·01	16·56	16·74	16·84	17·37	17·89	17·62	16·99	16·80	17·22
3 30	16·08	16·73	16·31	15·98	15·75	15·81	16·29	16·46	16·50	16·48	16·01	15·89	16·19
4 30	15·14	15·20	14·47	14·44	14·48	14·69	14·96	15·03	14·94	14·76	14·50	14·95	14·96
5 30	13·69	13·39	13·01	12·89	13·33	13·75	13·83	13·46	13·19	13·15	13·33	13·82	13·40
6 30	12·61	11·96	11·42	11·44	12·35	13·07	12·87	12·00	11·63	11·70	12·28	13·06	12·20
7 30	12·38	11·78	11·31	11·71	12·58	13·09	12·72	11·80	11·78	11·95	12·62	13·21	12·24
8 30	13·56	12·79	12·68	13·28	13·75	13·86	13·39	12·82	12·86	13·37	13·95	14·07	13·36
9 30	14·95	14·47	14·62	15·07	15·91	14·93	14·64	14·34	14·78	15·13	15·61	15·35	14·98
10 30	15·98	15·96	16·54	16·61	16·28	15·91	15·61	15·84	16·38	16·83	16·73	16·38	16·25
11 30	16·73	17·39	17·67	17·60	17·01	16·57	16·52	16·99	17·69	17·92	17·50	17·14	17·23

Table IV.

Showing the Difference in the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Mean Interval, for every month in the year.

Moon's Transit.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
h m	m	m	m	m	m	m	m	m	m	m	m	m
30	− 3·4	+ 1·2	+ 2·0	+ 2·3	− 0·8	− 3·7	− 3·6	+ 0·4	+ 3·3	+ 2·0	+ 1·3	− 4·2
1 30	− 1·2	+ 8·2	+ 3·2	+ 1·6	− 2·8	− 5·2	− 2·9	+ 3·8	+ 2·3	+ 1·0	− 2·0	− 5·9
2 30	+ 3·1	+ 5·8	+ 5·5	− 0·5	− 5·3	− 4·1	+ 1·3	+ 7·7	+ 4·9	− 1·6	− 4·8	− 3·1
3 30	+ 5·6	+ 5·8	+ 1·8	− 1·1	− 6·4	− 1·9	+ 6·1	+ 3·9	+ 2·5	− 4·8	− 7·4	− 8·4
4 30	+ 8·4	+ 4·6	− 2·4	− 8·5	− 6·7	+ 2·2	+10·4	+ 7·5	− 1·4	− 8·0	− 8·0	− 7·2
5 30	+10·5	+ 3·0	− 7·1	−10·5	− 4·5	+ 8·3	+10·9	+ 5·4	− 6·4	−11·1	− 6·2	+ 7·3
6 30	+ 8·3	− 3·1	−10·8	− 9·2	+ 0·9	+11·9	+10·6	− 2·6	− 8·9	−11·9	− 0·6	+11·5
7 30	+ 1·7	− 6·4	− 8·6	− 5·9	+ 6·2	+10·2	− 3·9	− 5·8	− 9·3	+ 3·4	+ 6·9	+ 7·3
8 30	− 4·4	− 4·8	− 1·5	+ 1·8	+ 4·7	+ 1·8	− 3·3	− 0·4	− 1·5	+ 7·3	+ 5·7	+ 7·9
9 30	− 5·4	+ 0·6	− 0·1	+ 3·9	+ 2·1	− 1·2	− 1·9	+ 1·9	+ 5·3	+ 3·6	+ 8·8	− 2·2
10 30	− 5·7	− 0·2	+ 0·7	+ 4·0	+ 2·7	− 2·4	− 4·6	+ 3·9	+ 2·2	+ 4·5	+ 2·5	− 2·0
11 30	+ 2·2	− 0·5	+ 1·4	+ 4·0	− 0·8	− 5·3	− 4·8	− 1·9	+ 3·2	+ 3·3	+ 0·9	− 4·3

Table V.

Showing the Difference in the Height of High Water and the Mean Height for every month in the year.

Moon's Transit.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
h m	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
30	−·26	+·32	+·65	+·28	−·40	−1·00	−·65	−·05	+·57	+·79	+·22	−·48
1 30	−·04	+·26	+·71	+·10	−·63	− ·94	−·64	+·18	+·61	+·50	−·05	−·50
2 30	+·30	+·47	+·41	−·21	−·66	− ·48	−·38	+·15	+·67	+·40	−·23	−·42
3 30	−·11	+·54	+·12	−·21	−·44	− ·38	+·10	+·27	+·31	+·29	−·18	−·30
4 30	+·18	+·24	−·49	−·52	−·48	− ·27	00	+·07	−·02	−·20	−·46	−·01
5 30	+·29	−·01	−·39	−·51	−·07	+ ·35	+·43	+·06	−·21	−·25	−·07	+·42
6 30	+·41	−·24	−·78	−·76	+·15	+ ·87	+·67	−·20	−·57	−·50	+·08	+·86
7 30	+·14	−·46	−·93	−·53	+·34	+ ·85	+·48	−·44	−·46	−·29	+·38	+·97
8 30	+·20	−·57	−·68	−·08	+·19	+ ·50	+·03	−·54	−·50	+·01	+·59	+·71
9 30	−·03	−·51	−·36	+·09	+·93	− ·05	−·34	−·64	−·20	+·15	+·63	+·37
10 30	−·27	−·29	+·29	+·36	+·03	− ·34	−·64	−·41	+·13	+·58	+·48	+·13
11 30	−·50	+·16	+·44	+·37	−·22	− ·66	−·71	−·24	+·46	+·69	+·27	−·09

The quantities in this and the preceding Table are chiefly owing to the correction for the Moon's Declination.

Table VI.

Showing the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Height of High Water, at the Liverpool Old Docks, corresponding to the Apparent Solar Time of the Moon's Transit, for every minute of her Horizontal Parallax.

Number of Observations.	Hor. Par. 54′. Moon's Transit.	Interval.	Height of Tide.	Moon's Decl.	Number of Observations.	Hor. Par. 55′. Moon's Transit.	Interval.	Height of Tide.	Moon's Decl.
	h m	h m	ft. in.	°		h m	h m	ft. in.	°
199	30·3	11 26·4	16 7·0	15	156	30·2	11 23·1	16 10·6	14
194	1 30·6	11 7·2	16 5·8	15	169	1 31·1	11 5·3	16 7·8	15
189	2 29·9	10 49·5	15 9·9	15	181	2 31·1	10 48·9	16 0·2	15
165	3 29·5	10 32·1	14 8·4	15	199	3 30·0	10 34·8	15 1·3	15
149	4 29·1	10 23·6	13 7·3	16	234	4 31·0	10 23·5	13 10·0	16
119	5 29·5	10 24·8	12 3·4	16	246	5 30·6	10 25·8	12 5·8	15
124	6 31·5	10 46·5	11 0·5	17	255	6 29·8	10 44·9	11 4·3	15
140	7 30·4	11 27·5	11 4·8	15	223	7 29·7	11 24·6	11 5·4	15
181	8 30·4	11 57·7	12 8·3	15	204	8 29·5	11 53·0	12 9·4	15
180	9 30·3	12 3·6	14 1·8	15	181	9 30·3	12 0·9	14 4·1	15
197	10 29·7	11 55·3	15 4·5	15	173	10 30·0	11 53·3	15 6·9	15
187	11 29·5	11 41·4	16 3·6	15	164	11 29·5	11 39·8	16 4·6	14
	Hor. Par. 56′.					Hor. Par. 57′.			
119	30·7	11 16·0	17 3·5	14	95	31·9	11 17·1	17 6·4	14
119	1 31·0	11 1·3	17 1·1	14	109	1 31·5	11 1·9	17 7·6	14
113	2 30·0	10 46·3	16 8·1	14	108	2 30·3	10 45·6	17 0·4	14
145	3 29·8	10 33·7	15 7·0	15	117	3 30·6	10 33·3	16 2·0	14
144	4 31·3	10 24·0	14 2·1	15	131	4 30·7	10 24·6	14 10·6	14
139	5 30·9	10 24·7	12 10·8	15	148	5 29·8	10 32·3	13 4·8	15
162	6 29·3	10 43·2	11 8·5	15	136	6 30·4	10 41·1	12 6·3	15
143	7 29·7	11 19·9	12 1·2	15	132	7 30·3	11 16·0	12 4·0	14
140	8 30·3	11 41·1	13 1·9	14	115	8 29·7	11 43·7	13 4·2	15
129	9 30·7	11 56·5	14 8·1	14	111	9 29·9	11 51·5	14 9·5	14
121	10 31·0	11 49·4	15 11·9	14	108	10 29·7	11 46·7	16 0·3	14
114	11 32·7	11 36·3	16 9·9	15	105	11 30·2	11 33·1	17 0·0	14
	Hor. Par. 58′.					Hor. Par. 59′.			
91	30·4	11 15·7	17 11·6	13	99	30·1	11 13·2	18 4·5	14
97	1 28·4	10 59·2	18 1·4	14	99	1 32·1	10 56·5	18 5·6	14
105	2 30·2	10 45·2	17 6·4	14	111	2 30·8	10 42·5	18 0·4	15
128	3 31·2	10 31·2	16 7·0	14	136	3 30·6	10 30·8	17 2·3	14
131	4 32·2	10 23·0	15 4·3	15	200	4 32·4	10 21·8	15 10·5	15
148	5 31·4	10 24·5	14 0·0	15	290	5 31·4	10 21·8	14 5·9	15
150	6 30·6	10 38·5	12 10·0	14	299	6 29·0	10 34·8	13 3·4	15
138	7 30·5	11 10·7	12 8·0	15	194	7 28·8	11 0·8	12 11·6	15
119	8 29·0	11 37·2	13 9·1	14	140	8 29·4	11 31·0	13 11·2	15
107	9 29·4	11 46·7	15 1·0	14	108	9 29·2	11 41·8	15 5·1	15
101	10 30·6	11 42·2	16 5·2	13	100	10 29·0	11 38·5	16 7·4	14
88	11 29·9	11 29·3	17 3·1	14	103	11 30·3	11 25·9	17 8·0	14
	Hor. Par. 60′.					Hor. Par. 61′.			
105	32·6	11 10·6	18 7·7	15	212	30·6	11 6·0	19 2·2	15
111	1 32·3	10 54·9	19 0·9	15	200	1 29·3	10 52·0	19 4·7	15
161	2 34·1	10 40·1	18 8·8	15	133	2 25·8	10 39·3	18 10·9	16
226	3 29·7	10 28·2	17 8·7	16					
147	4 27·0	10 20·5	16 3·4	16					
23	5 16·7	10 14·7	15 0·4	15					
21	6 45·7	10 43·1	13 0·8	16					
148	7 24·4	11 4·6	13 3·4	16					
226	8 32·0	11 25·8	14 1·7	16					
163	9 28·0	11 37·9	15 7·6	15	125	9 35·5	11 33·7	15 11·4	15
114	10 30·7	11 34·3	17 0·6	15	196	10 30·9	11 30·1	17 3·9	15
110	11 31·3	11 23·1	18 1·1	14	212	11 30·7	11 19·7	18 5·6	15

Mean of the preceding.

Moon's Transit.	Interval.	Height of Tide.
h m	h m	ft. in.
0 30·8	11 16·0	17 9·7
1 30·8	11 0·0	17 10·2
2 30·3	10 44·7	17 4·0
3 30·2	10 32·0	16 2·0
4 30·5	10 23·0	14 10·3
5 27·6	10 22·8	13 6·2
6 32·3	10 41·7	12 3·0
7 29·1	11 14·9	12 3·8
8 30·0	11 41·3	13 5·0
9 30·4	11 49·0	15 0·0
10 30·2	11 43·7	16 3·4
11 30·5	11 31·0	17 3·0

Table VII. (Interpolated from Table VI.)

Moon's Transit.	H. P. 54′.		H. P. 55′.		H. P. 56′.		H. P. 57′.		H. P. 58′.		H. P. 59′.		H. P. 60′.		H. P. 61′.	
	Interval.	Height of Tide.	Interval.	Height of Tide.	Interval.	Height of Tide.	Interval.	Height of Tide.	Interval.	Height of Tide.	Interval.	Height of Tide.	Interval.	Height of Tide.	Interval.	Height of Tide.
h m	h m	ft.	h m	ft.	h m	ft.	h m	ft.	h m	ft.	h m	ft.	h m	ft.	h m	ft.
30	11 26·4	16·58	11 23·1	16·88	11 16·3	17·29	11 18·1	17·53	11 15·9	17·96	11 13·2	18·37	11 11·8	18·62	11 6·3	19·17
1 30	11 7·5	16·46	11 4·7	16·64	11 1·8	17·09	11 2·6	17·63	10 58·4	18·12	10 57·5	18·45	10 56·0	19·09	10 51·7	19·39
2 30	10 49·5	15·82	10 49·5	16·02	10 46·3	16·67	10 45·7	17·04	10 45·1	17·54	10 42·8	18·04	10 41·9	18·75	10 38·4	18·87
3 30	10 31·3	14·69	10 34·8	15·11	10 33·6	15·58	10 33·5	16·17	10 31·6	16·58	10 31·0	17·19	10 28·1	17·70		
4 30	10 23·7	13·59	10 23·7	13·86	10 24·3	14·20	10 24·7	14·89	10 23·3	15·36	10 21·9	15·87	10 19·8	17·72		
5 30	10 25·0	12·28	10 25·8	12·49	10 24·7	12·91	10 23·3	13·39	10 24·3	14·01	10 21·8	14·49				
6 30	10 45·3	11·07	10 45·1	11·36	10 43·8	11·70	10 40·8	12·53	10 38·1	12·84	10 35·5	13·29				
7 30	11 27·0	11·39	11 24·9	11·45	11 20·2	12·10	11 15·7	12·33	11 10·2	12·66	11 1·9	12·96	11 8·5	13·29		
8 30	11 57·5	12·68	11 53·3	12·79	11 48·4	13·15	11 43·9	13·36	11 37·8	13·77	11 31·4	13·93	11 24·7	14·10		
9 30	12 3·6	14·14	12 0·8	14·33	11 56·2	14·66	11 51·5	14·79	11 47·8	15·09	11 41·9	15·42	11 38·3	15·68	11 33·5	16·06
10 30	11 55·2	15·38	11 53·3	15·57	11 49·6	15·97	11 46·6	16·04	11 42·3	16·43	11 38·3	16·62	11 34·6	17·04	11 30·3	17·31
11 30	11 41·2	16·30	11 39·6	16·39	11 34·9	16·79	11 32·2	17·00	11 29·3	17·26	11 26·0	17·66	11 22·9	18·08	11 19·9	18·45

Table VIII.

Showing the Difference in the Interval between the Time of the Moon's Transit and the Time of High Water, and the Interval corresponding to fifty-seven minutes of the Moon's Horizontal Parallax.

Moon's Transit.	H. P. 54′.	H. P. 55′.	H. P. 56′.	H. P. 57′.	H. P. 58′.	H. P. 59′.	H. P. 60′.	H. P. 61′.
h m	m	m	m	m	m	m	m	m
30	+ 8·3	+5·0	−1·8	0	−2·2	− 4·9	− 6·3	−11·8
1 30	+ 4·9	+2·1	+0·8	0	−4·2	− 5·1	− 6·6	−10·9
2 30	+ 3·8	+3·8	+0·6	0	−0·6	− 2·9	− 3·8	− 7·3
3 30	− 2·2	+1·3	+0·1	0	−1·9	− 2·5	− 5·4	
4 30	− 1·0	−1·0	−0·4	0	−1·4	− 2·8	− 4·9	
5 30	+ 1·7	+2·5	+1·4	0	+1·0	− 1·5		
6 30	+ 4·5	+4·3	+3·0	0	−2·7	− 5·3		
7 30	+11·3	+9·2	+4·5	0	−5·5	−13·8	− 7·2	
8 30	+13·6	+9·4	+4·5	0	−6·1	−12·5	−19·2	
9 30	+12·1	+9·3	+4·7	0	−3·7	− 9·6	−13·2	−18·0
10 30	+ 8·6	+6·7	+3·0	0	−4·3	− 8·3	−12·0	−16·3
11 30	+ 8·0	+6·4	+1·7	0	−3·9	− 7·2	−10·3	−13·3

Table IX.

Showing the Difference between the Height of High Water and the Height corresponding to fifty-seven minutes of the Moon's Horizontal Parallax.

Moon's Transit.	H. P. 54′.	H. P. 55′.	H. P. 56′.	H. P. 57′.	H. P. 58′.	H. P. 59′.	H. P. 60′.	H. P. 61′.
h m	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
30	− ·95	− ·65	−·24	0	+·46	+ ·84	+1·09	+1·64
1 30	−1·17	− ·99	−·54	0	+·49	+ ·82	+1·46	+1·76
2 30	−1·22	−1·02	−·37	0	+·50	+1·00	+1·71	+1·83
3 30	−1·48	−1·06	−·59	0	+·41	+1·02	+1·53	
4 30	−1·30	−1·03	−·69	0	+·47	+ ·98	+2·83	
5 30	−1·11	− ·90	−·48	0	+·62	+1·10		
6 30	−1·46	−1·17	−·83	0	+·31	+ ·76		
7 30	− ·94	− ·88	−·23	0	+·33	+ ·63	+ ·96	
8 30	− ·68	− ·57	−·21	0	+·41	+ ·57	+ ·74	
9 30	− ·65	− ·46	−·13	0	+·30	+ ·63	+ ·89	+1·27
10 30	− ·66	− ·47	−·07	0	+·39	+ ·58	+1·00	+1·27
11 30	− ·70	− ·61	−·21	0	+·26	+ ·66	+1·08	+1·45

Table X.

Showing the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Height of High Water, at the Liverpool Old Docks, corresponding to the Apparent Solar Time of the Moon's Transit, for every three degrees of her Declination north and south. The Equation of Time to be added to Apparent Time.

Number of Observations.	1° 30′ N. to 1° 30′ South Declination.					Number of Observations.	1° 30′ to 4° 30′ North Declination.					Number of Observations.	4° 30′ to 7° 30′ North Declination.				
	Moon's Transit.	Equation of Time.	Interval.	Height of Tide.	Hor. Par.		Moon's Transit.	Equation of Time.	Interval.	Height of Tide.	Hor. Par.		Moon's Transit.	Equation of Time.	Interval.	Height of Tide.	Hor. Par.
	h m	m	h m	ft. in.	′		h m	m	h m	ft. in.	′		h m	m	h m	ft. in.	′
48	29·3	+ 2·5	11 22·2	18 4·0	57·0	54	27·3	+ 2·2	11 21·1	18 3·5	57·2	55	31·3	+ 1·6	11 19·6	18 2·0	57·3
45	1 29·5	+ 6·0	11 5·0	18 3·3	57·4	52	1 30·0	+ 6·3	11 5·7	18 3·7	57·1	47	1 30·9	+ 6·5	11 5·7	18 5·9	57·2
52	2 28·7	+ 9·2	10 51·6	17 6·0	57·0	45	2 29·2	+ 8·2	10 51·4	17 1·1	57·5	48	2 30·9	+ 6·8	10 50·4	17 8·5	57·1
51	3 28·2	+ 8·8	10 39·3	16 9·5	57·1	54	3 33·2	+ 8·6	10 37·5	16 4·5	57·0	48	3 29·1	+ 7·8	10 38·6	16 4·7	56·8
46	4 31·3	+ 6·1	10 31·4	15 0·1	56·8	50	4 30·2	+ 6·1	10 28·1	15 2·1	56·9	46	4 31·8	+ 5·5	10 31·0	15 0·0	57·0
44	5 30·9	+ 2·8	10 34·5	14 1·3	57·0	42	5 31·0	+ 2·6	10 35·4	13 7·4	56·7	42	5 31·3	+ 2·3	10 42·4	13 9·1	56·7
39	6 30·6	− 2·3	10 54·8	13 0·9	56·8	49	6 29·5	+ 2·1	10 54·0	13 1·6	56·9	45	6 31·8	− 2·8	10 52·6	12 8·2	57·3
46	7 29·7	− 5·8	11 23·3	12 11·0	56·8	43	7 29·0	− 6·6	11 23·6	13 2·9	57·1	45	7 30·0	− 5·2	11 24·2	13 2·4	58·2
47	8 28·5	− 9·1	11 46·8	14 1·3	57·0	47	8 27·3	− 7·9	11 47·0	13 10·0	57·0	44	8 31·1	− 7·2	11 49·9	13 5·9	56·4
46	9 28·6	− 9·3	11 53·8	15 1·6	57·1	43	9 27·6	− 8·9	11 50·1	15 5·6	57·4	53	9 28·2	− 7·7	11 53·8	15 2·0	57·1
55	10 33·3	− 6·5	11 47·8	16 10·5	57·3	50	10 27·5	− 6·4	11 44·2	16 8·4	57·0	46	10 33·8	− 5·2	11 46·7	16 8·6	57·3
40	11 34·1	− 2·2	11 33·5	16 10·3	57·9	45	11 25·3	− 2·7	11 37·4	17 7·6	57·3	50	11 31·0	− 1·7	11 34·3	17 2·9	57·5

	1° 30′ to 4° 30′ South Declination.						4° 30′ to 7° 30′ South Declination.					
52	30·4	+ 3·0	11 18·3	18 6·6	57·7	53	29·8	+ 2·5	11 20·4	18 0·0	57·3	
41	1 30·5	+ 7·0	11 3·6	18 3·5	58·0	43	1 31·3	+ 6·0	11 5·2	18 6·0	57·6	
48	2 30·9	+ 8·1	10 49·8	17 7·1	57·5	46	2 31·3	+ 8·0	10 50·4	17 8·7	57·6	
41	3 31·9	+ 8·3	10 39·9	16 6·2	56·7	44	2 32·0	+ 7·9	10 38·3	16 6·4	57·3	
41	4 29·3	+ 6·6	10 31·6	15 5·3	57·2	45	4 30·0	+ 5·0	10 29·6	15 5·2	56·8	
45	5 29·0	+ 2·3	10 34·5	13 9·1	56·6	47	5 27·0	+ 3·1	10 32·7	14 1·4	57·0	
49	6 30·1	+ 1·1	10 53·5	12 11·4	57·0	51	6 29·4	− 2·1	10 51·0	12 10·3	57·0	
44	7 33·1	− 6·5	11 27·1	13 0·1	57·0	50	7 30·4	− 5·1	11 21·6	12 11·5	57·0	
45	8 32·4	− 8·1	11 41·3	13 1·6	57·3	40	8 29·0	− 6·8	11 47·0	13 10·0	56·9	
54	9 30·0	− 8·6	11 54·4	15 3·8	56·7	48	9 31·9	− 7·5	11 54·5	15 6·3	57·2	
47	10 28·5	− 6·0	11 41·8	16 8·0	57·3	46	10 30·3	− 5·6	11 44·9	16 11·5	57·8	
54	11 31·1	− 4·6	11 34·8	17 9·0	57·4	52	11 30·2	− 1·9	11 32·0	18 0·0	57·7	

	7° 30′ to 10° 30′ North Declination.						10° 30′ to 13° 30′ North Declination.						13° 30′ to 16° 30′ North Declination.					
52	30·1	+ 1·3	11 20·3	18 1·1	57·1	54	30·8	+ 1·2	11 19·3	18 0·1	57·3	58	31·6	+ 0·1	11 18·8	17 9·6	58·7	
54	1 30·7	+ 4·3	11 4·7	18 2·1	57·2	64	1 32·3	+ 2·3	11 3·4	17 10·2	58·2	54	1 28·0	0·0	11 3·1	17 7·8	58·7	
50	2 28·7	+ 6·0	10 49·2	17 5·1	57·3	45	2 31·7	+ 3·8	10 48·8	17 4·5	57·0	66	2 28·9	+ 1·5	10 47·3	16 10·8	58·8	
53	3 27·8	+ 5·9	10 41·5	16 5·2	56·6	53	3 29·9	+ 3·9	10 35·3	16 0·4	56·8	67	3 27·6	+ 0·1	10 33·2	16 1·7	56·5	
54	4 29·7	+ 5·1	10 30·3	14 11·3	56·7	51	4 30·7	+ 2·6	10 28·0	14 10·4	56·7	71	4 28·8	+ 0·1	10 25·2	14 8·1	56·4	
45	5 28·9	+ 1·2	10 32·1	13 9·4	56·4	57	5 30·4	+ 1·3	10 27·4	13 6·3	56·7	75	5 29·0	+ 1·0	10 27·1	13 2·1	56·2	
51	6 27·5	− 1·5	10 49·7	12 8·3	56·6	64	6 30·4	− 1·2	10 48·0	12 4·6	56·5	72	6 30·6	0·0	10 44·7	12 3·1	56·4	
47	7 27·8	− 4·3	11 22·5	12 7·2	56·5	60	7 27·4	− 2·3	11 20·1	12 6·5	56·5	69	7 32·2	− 1·0	11 20·8	12 1·6	56·3	
48	8 31·7	− 6·6	11 45·2	14 1·7	57·1	59	8 30·0	− 4·2	11 48·5	13 7·7	56·5	63	8 31·4	− 0·3	11 46·0	13 4·3	56·7	
58	9 30·2	− 6·2	11 54·8	15 1·3	56·7	59	9 30·5	− 2·4	11 52·0	14 11·2	57·0	64	9 31·3	− 0·4	11 52·6	14 11·3	56·0	
51	10 33·3	− 4·5	11 46·4	16 6·7	57·3	60	10 29·1	− 2·6	11 48·5	16 2·6	56·9	71	10 29·4	− 0·8	11 46·6	16 6·1	56·8	
47	11 30·8	− 1·1	11 35·6	17 7·9	56·9	61	11 27·0	− 1·4	11 36·6	17 2·5	56·8	70	11 32·5	0·0	11 34·1	17 1·1	56·8	

	7° 30′ to 10° 30′ South Declination.						10° 30′ to 13° 30′ South Declination.						13° 30′ to 16° 30′ South Declination.					
42	29·9	+ 1·2	11 18·7	18 4·9	57·8	54	30·6	+ 1·4	11 16·3	18 4·7	57·9	61	31·2	0·0	11 15·2	18 2·5	58·0	
53	1 29·0	+ 4·8	11 3·9	18 5·0	57·7	57	1 30·3	+ 2·7	11 1·8	18 5·4	57·8	61	1 31·2	− 0·1	11 0·3	18 2·6	58·5	
52	2 30·5	+ 5·2	10 49·1	17 8·2	57·3	59	2 30·5	+ 4·0	10 46·8	17 8·1	57·7	60	2 29·2	+ 0·6	10 45·0	17 6·6	57·6	
51	3 27·3	+ 5·8	10 37·0	16 9·9	57·4	48	3 30·3	+ 4·1	10 35·5	16 7·8	57·4	62	3 30·6	+ 0·4	10 32·6	16 4·8	57·5	
49	4 32·3	+ 5·6	10 29·5	15 1·8	57·4	59	4 28·9	+ 3·1	10 27·3	15 1·9	57·1	60	4 30·5	+ 0·7	10 23·5	15 1·7	57·3	
46	5 32·7	+ 1·1	10 32·1	13 8·7	56·9	57	5 30·8	+ 1·4	10 29·0	13 10·7	57·3	64	5 29·0	+ 0·3	10 25·0	14 1·0	57·1	
44	6 32·6	− 1·2	10 49·3	13 0·0	57·2	59	6 28·7	− 1·9	10 45·0	12 6·6	57·0	58	6 30·6	0·0	10 42·6	12 7·5	57·3	
46	7 31·0	− 5·7	11 22·0	12 6·4	56·9	49	7 30·0	− 3·6	11 16·6	12 7·5	57·5	64	7 30·2	− 0·8	11 14·9	12 7·9	57·5	
54	8 28·5	− 5·5	11 43·4	13 10·3	57·5	53	8 28·4	− 4·0	11 42·4	13 7·8	57·3	73	8 31·0	− 0·9	11 40·6	13 6·3	57·4	
50	9 30·0	− 4·8	11 52·2	15 8·3	57·3	55	9 30·6	− 3·2	11 49·2	15 1·4	57·7	63	9 31·5	− 1·1	11 47·9	15 1·6	57·8	
53	10 29·4	− 4·9	11 46·0	16 7·5	57·6	53	10 30·5	− 1·5	11 45·3	16 9·0	57·7	67	10 30·7	− 0·3	11 42·2	16 7·0	57·9	
51	11 30·3	− 2·5	11 33·0	18 1·9	57·8	65	11 31·5	− 1·2	11 31·6	17 7·2	57·8	54	11 30·7	+ 0·2	11 29·5	17 4·6	58·0	

Table X.- (Continued.)

Number of Observations.	Moon's Transit.	Equation of Time.	Interval.	Height of Tide.	Hor. Par.
	16° 30′ to 19° 30′ North Declination.				
	h m	m	h m	ft. in.	′
92	32·6	− 0·4	11 18·4	17 1·0	56·3
95	1 31·6	− 3·0	11 1·0	17 2·1	56·5
97	2 31·3	− 4·0	10 45·0	16 8·7	56·5
93	3 30·8	− 3·8	10 31·0	15 10·9	56·1
100	4 31·6	− 2·6	10 21·7	14 4·3	56·1
94	5 30·7	− 1·5	10 21·6	12 9·5	56·0
95	6 29·5	+ 0·9	10 41·5	11 10·5	55·8
106	7 31·0	+ 2·7	11 16·8	12 0·0	56·2
89	8 31·1	+ 3·2	11 44·8	13 3·0	56·2
102	9 28·8	+ 4·2	11 52·8	14 7·0	56·2
95	10 30·6	+ 1·9	11 45·1	15 11·0	56·5
91	11 32·3	+ 1·2	11 33·3	16 9·9	56·4
	16° 30′ to 19° 30′ South Declination.				
83	29·9	− 0·9	11 2·4	17 11·2	58·2
84	1 30·1	− 2·0	10 56·6	18 2·5	58·7
87	2 28·6	− 3·3	10 42·3	17 9·9	58·2
93	3 29·0	− 4·1	10 35·2	16 9·1	58·4
96	4 30·3	− 3·2	10 21·4	14 10·5	57·8
98	5 30·5	− 0·7	10 18·8	13 7·5	57·5
100	6 31·7	+ 1·0	10 35·5	12 9·9	57·5
92	7 31·1	+ 3·0	11 8·6	12 7·9	57·9
91	8 31·6	+ 3·1	11 36·4	13 8·0	57·9
80	9 31·2	+ 4·4	11 42·8	15 2·5	58·0
88	10 29·0	+ 2·8	11 39·1	16 5·7	58·3
83	11 31·9	+ 0·9	11 26·3	17 5·8	58·7
	19° 30′ to 22° 30′ North Declination.				
62	31·0	− 1·7	11 11·4	17 9·7	58·4
61	1 33·1	− 3·6	10 55·7	17 5·1	58·0
56	2 31·0	− 4·1	10 39·4	17 2·0	58·1
72	3 31·1	− 4·1	10 28·0	16 1·5	57·5
64	4 29·9	− 2·6	10 17·7	14 11·0	57·8
67	5 28·0	− 0·3	10 17·8	13 5·0	57·4
70	6 30·1	+ 0·8	10 33·6	12 2·7	57·6
63	7 32·0	+ 3·4	11 7·2	12 2·5	57·8
62	8 28·8	+ 4·3	11 36·7	13 3·6	57·7
65	9 29·8	+ 3·7	11 45·7	14 6·4	57·2
62	10 28·8	+ 3·6	11 39·2	16 2·1	58·1
62	11 30·6	+ 1·0	11 26·2	17 0·1	58·3
	19° 30′ to 22° 30′ South Declination.				
65	30·3	− 0·8	11 15·4	17 1·2	56·9
67	1 27·8	− 4·0	11 0·2	17 0·4	56·5
71	2 29·0	− 5·2	10 41·4	16 5·6	56·7
70	3 28·8	− 3·6	10 28·6	15 9·9	56·6
74	4 30·7	− 3·4	10 18·1	14 4·5	56·3
64	5 32·5	0·8	10 18·1	12 8·2	56·2
75	6 30·7	+ 1·3	10 35·3	11 5·2	56·1
65	7 28·5	+ 3·0	11 2·1	11 7·4	56·4
68	8 29·7	+ 4·5	11 44·7	12 7·5	56·1
67	9 28·7	+ 4·5	11 48·8	14 5·7	57·2
67	10 31·8	+ 3·4	11 45·0	15 8·5	56·6
63	11 31·3	+ 1·2	11 32·0	16 7·1	56·9
	22° 30′ to 25° 30′ North Declination.				
48	30·8	− 1·3	11 7·6	17 5·3	58·7
57	1 33·3	− 4·7	10 51·8	17 8·9	58·8
45	2 32·0	− 6·6	10 35·4	17 4·4	58·5
54	3 29·5	− 6·0	10 23·5	16 5·5	58·2
51	4 30·0	− 5·5	10 13·5	15 0·5	58·2
56	5 29·2	− 0·4	10 14·0	13 5·7	57·7
54	6 31·9	+ 1·2	10 29·9	12 1·7	57·7
52	7 27·4	+ 4·2	11 2·5	11 11·4	58·0
61	8 34·6	+ 5·1	11 29·8	13 2·1	58·1
50	9 30·2	+ 7·2	11 38·5	14 11·1	58·8
52	10 30·5	+ 4·4	11 35·3	15 11·7	58·5
58	11 30·3	+ 1·4	11 25·6	16 9·0	58·0
	Above 25° 30′ North Declination.				
42	31·4	− 2·9	11 1·5	16 4·2	56·8
45	1 28·7	− 5·8	10 55·0	16 1·4	56·3
49	2 31·8	− 7·7	10 35·5	15 11·5	56·2
51	3 31·0	− 7·5	10 22·6	15 1·0	56·3
59	4 32·5	− 5·9	10 9·8	13 7·9	56·1
53	5 33·1	− 1·7	10 9·7	12 3·7	56·2
58	6 29·8	+ 1·9	10 25·4	10 9·0	56·1
54	7 31·4	+ 5·2	11 6·0	10 10·0	56·5
51	8 30·5	+ 8·5	11 44·3	12 1·6	55·9
44	9 30·2	+ 7·6	11 51·0	13 8·3	56·3
47	10 28·9	+ 6·0	11 43·2	15 0·0	56·2
41	11 30·4	+ 2·2	11 30·0	15 6·2	56·4
	22° 30′ to 25° 30′ South Declination.				
57	31·9	− 1·8	11 16·1	16 5·1	56·1
52	1 30·8	− 4·6	10 57·4	16 5·6	56·1
61	2 32·1	− 6·2	10 40·2	16 0·8	56·0
50	3 28·9	− 5·7	10 26·1	15 5·7	55·7
65	4 30·0	− 3·6	10 15·4	13 11·9	55·9
50	5 30·6	− 1·9	10 12·6	12 6·4	55·8
63	6 28·5	+ 0·7	10 30·1	11 2·6	57·2
60	7 32·3	+ 3·9	11 13·0	11 3·9	56·2
62	8 30·8	+ 6·3	11 44·1	12 6·9	56·0
57	9 32·4	+ 6·1	11 52·7	14 2·3	56·0
52	10 29·0	+ 5·3	11 46·8	15 1·3	56·2
51	11 32·4	+ 1·4	11 30·2	16 4·0	56·8
	Above 25° 30′ South Declination.				
42	28·5	− 2·0	11 6·9	17 2·5	58·3
41	1 30·0	− 5·4	10 50·0	17 5·6	58·4
43	2 28·6	− 7·5	10 34·3	17 0·1	58·4
49	3 30·7	− 7·9	10 20·9	16 1·0	58·0
50	4 31·8	− 6·7	10 9·5	14 8·2	57·7
52	5 28·8	− 1·9	10 8·1	13 2·8	57·7
59	6 29·2	+ 1·5	10 22·2	11 6·5	57·4
47	7 29·1	+ 6·0	10 54·3	11 6·8	58·0
52	8 30·0	+ 7·3	11 30·0	12 10·9	57·8
42	9 29·7	+ 8·6	11 40·0	14 3·6	58·2
44	10 32·7	+ 6·1	11 35·0	15 6·0	58·2
37	11 30·4	+ 2·9	11 20·0	16 5·6	58·7

In forming this Table, it has been assumed that Mr. Hutchinson's clock was regulated according to *apparent* solar time; if it was regulated according to *mean* solar time, the interval must be *diminished* by the equation of time given in the third column.

Table XI. (Interpolated from Table X.)

Showing the Interval between the Apparent Time of the Moon's Transit and the Time of High Water at the Liverpool Old Docks for every three degrees of her Declination north *and* south.

Moon's Transit.	0° Dec.	3° N. Dec.	6° N. Dec.	9° N. Dec.	12° N. Dec.	15° N. Dec.	18° N. Dec.	21° N. Dec.	24° N. Dec.	27° N. Dec.	Mean.
h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
30	11 22·1	11 20·4	11 19·9	11 20·3	11 19·5	11 19·2	11 19·0	11 11·7	11 7·8	11 11·9	11 17·2
1 30	11 5·0	11 5·7	11 5·7	11 4·9	11 4·0	11 2·5	11 1·4	10 56·5	11 52·7	10 54·6	11 1·3
2 30	10 51·4	10 51·2	10 50·6	10 49·4	10 49·2	10 47·0	10 45·3	10 39·6	10 35·9	10 36·0	10 45·6
3 30	10 39·1	10 38·1	10 38·5	10 37·0	10 35·3	10 32·8	10 31·2	10 28·2	10 23·4	10 22·8	10 32·6
4 30	10 31·6	10 28·1	10 31·2	10 30·3	10 28·1	10 25·0	10 21·8	10 17·7	10 13·5	10 10·0	10 23·8
5 30	10 34·5	10 35·3	10 35·3	10 32·2	10 27·4	10 27·1	10 21·6	10 17·5	10 14·1	10 9·7	10 25·5
6 30	10 54·7	10 54·0	10 52·2	10 50·7	10 48·0	10 44·5	10 41·6	10 33·6	10 29·4	10 25·4	10 43·4
7 30	11 23·4	11 24·0	11 24·2	11 23·2	11 20·2	11 19·7	11 16·3	11 6·2	11 3·7	11 5·0	11 16·6
8 30	11 47·1	11 47·4	11 49·5	11 45·6	11 48·5	11 45·6	11 44·0	11 37·1	11 30·7	11 43·0	11 43·6
9 30	11 53·8	11 50·0	11 53·7	11 54·8	11 52·0	11 52·5	11 52·8	11 45·7	11 38·5	11 51·0	11 50·5
10 30	11 48·1	11 44·0	11 47·0	11 47·0	11 48·6	11 46·5	11 45·2	11 39·1	11 35·4	11 43·1	11 44·4
11 30	11 34·4	11 36·5	11 34·4	11 35·7	11 36·0	11 34·7	11 33·9	11 26·4	11 25·6	11 30·1	11 32·8
		3° S. Dec.	6° S. Dec.	9° S. Dec.	12° S. Dec.	15° S. Dec.	18° S. Dec.	21° S. Dec.	24° S. Dec.	27° S. Dec.	Mean.
30		11 18·4	11 20·4	11 18·7	11 16·4	11 15·5	11 12·4	11 15·4	11 16·6	11 6·6	11 15·6
1 30		11 3·7	11 5·7	11 3·7	11 1·8	11 0·0	10 56·6	10 59·6	10 57·6	10 50·0	10 59·9
2 30		10 50·0	10 50·9	10 49·2	10 46·9	10 44·9	10 42·0	10 41·1	10 40·5	10 34·0	10 44·3
3 30		10 40·2	10 38·7	10 36·6	10 35·5	10 32·7	10 35·1	10 28·3	10 25·9	10 21·0	10 32·6
4 30		10 31·5	10 29·6	10 29·9	10 27·2	10 23·6	10 21·4	10 18·2	10 15·4	10 9·8	10 22·9
5 30		10 34·7	10 33·0	10 32·0	10 29·0	10 25·1	10 18·8	10 18·0	10 12·6	10 8·2	10 23·4
6 30		10 53·5	10 51·2	10 48·7	10 44·4	10 42·4	10 35·0	10 35·1	10 31·8	10 22·4	10 41·0
7 30		11 25·9	11 21·4	11 21·6	11 16·6	11 14·9	11 8·1	11 2·9	11 13·0	10 54·8	11 13·2
8 30		11 40·7	11 47·4	11 43·7	11 42·8	11 40·2	11 36·4	11 44·7	11 44·1	11 30·0	11 41·0
9 30		11 54·4	11 54·4	11 52·2	11 49·1	11 47·8	11 42·7	11 48·8	11 52·7	11 40·0	11 49·1
10 30		11 41·6	11 44·9	11 45·9	11 45·3	11 42·3	11 39·0	11 45·1	11 46·8	11 35·2	11 42·9
11 30		11 34·7	11 32·0	11 33·0	11 32·0	11 29·6	11 26·6	11 32·4	11 30·2	11 20·1	11 30·1

Table XII.

Showing the Interval between the Apparent Time of the Moon's Transit and the Time of High Water at the Liverpool Old Docks for every three degrees of her Declination north *or* south.

Moon's Transit.	0° Dec.	3° Dec.	6° Dec.	9° Dec.	12° Dec.	15° Dec.	18° Dec.	21° Dec.	24° Dec.	27° Dec.	Mean.
h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
30	11 22·1	11 19·4	11 20·1	11 19·5	11 17·9	11 17·3	11 15·7	11 13·5	11 12·2	11 9·2	11 16·7
1 30	11 5·0	11 4·7	11 5·7	11 4·3	11 2·9	11 1·2	10 59·0	10 58·0	10 55·2	10 52·3	11 0·8
2 30	10 51·4	10 50·6	10 50·8	10 49·3	10 48·0	10 46·0	10 43·6	10 40·4	10 38·2	10 35·0	10 45·3
3 30	10 39·1	10 39·1	10 38·6	10 38·9	10 35·4	10 32·8	10 33·2	10 28·2	10 24·6	10 21·9	10 33·2
4 30	10 31·6	10 29·8	10 30·4	10 30·1	10 27·3	10 24·3	10 21·6	10 17·9	10 14·4	10 9·9	10 23·7
5 30	10 34·5	10 35·0	10 34·1	10 32·1	10 28·2	10 26·1	10 20·2	10 17·7	10 13·3	10 9·0	10 25·0
6 30	10 54·7	10 53·8	10 51·7	10 49·7	10 46·2	10 43·4	10 38·3	10 34·3	10 30·6	10 23·9	10 42·6
7 30	11 23·4	11 25·0	11 22·8	11 22·4	11 18·4	11 17·9	11 12·2	11 4·6	11 8·3	10 59·9	11 15·5
8 30	11 47·1	11 44·0	11 48·4	11 44·7	11 45·6	11 42·9	11 40·1	11 40·9	11 36·3	11 36·5	11 42·7
9 30	11 53·8	11 52·2	11 54·0	11 53·5	11 50·6	11 50·1	11 47·7	11 47·2	11 45·6	11 45·5	11 50·0
10 30	11 48·1	11 42·8	11 46·0	11 46·4	11 46·9	11 44·4	11 42·1	11 42·1	11 41·1	11 39·2	11 43·9
11 30	11 34·4	11 35·6	11 33·2	11 34·3	11 34·0	11 32·1	11 30·2	11 29·4	11 27·9	11 25·1	11 31·6

Table XIII.

Showing the Difference in the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Interval corresponding to fifteen degrees Declination, for every three degrees of her Declination north *and* south.

Moon's Transit.	0	3° N. Dec.	6° N. Dec.	9° N. Dec.	12° N. Dec.	15° N. Dec.	18° N. Dec.	21° N. Dec.	24° N. Dec.	27° N. Dec.
h m	m	m	m	m	m	m	m	m	m	m
30	+ 2·9	+ 1·2	+ 0·7	+ 1·1	+ 0·3	0	− 0·2	− 7·5	−11·4	− 7·3
1 30	+ 2·5	+ 3·2	+ 3·2	+ 2·4	+ 1·5	0	− 1·1	− 6·0	− 9·8	− 7·9
2 30	+ 4·4	+ 4·2	+ 3·6	+ 2·4	+ 2·2	0	− 1·7	− 7·4	−11·1	−11·0
3 30	+ 6·3	+ 5·3	+ 5·7	+ 8·4	+ 2·5	0	− 1·6	− 4·6	− 9·4	−10·0
4 30	+ 6·6	+ 3·1	+ 6·2	+ 5·3	+ 3·1	0	− 3·2	− 7·3	−11·5	−15·0
5 30	+ 7·4	+ 8·2	+ 8·2	+ 5·1	+ 0·3	0	− 5·5	− 9·6	−13·0	−17·4
6 30	+10·2	+ 9·5	+ 7·7	+ 6·2	+ 3·5	0	− 2·9	−10·9	−15·1	−19·1
7 30	+ 3·7	+ 4·3	+ 4·5	+ 3·5	+ 0·5	0	− 3·4	−13·5	−16·0	−14·7
8 30	+ 1·5	+ 1·8	+ 3·9	0·0	+ 2·9	0	− 1·6	− 8·5	−17·0	− 2·6
9 30	+ 1·3	− 2·5	+ 1·2	+ 2·3	− 0·5	0	+ 0·3	− 6·8	−14·0	− 1·5
10 30	+ 1·6	− 2·5	+ 0·5	+ 0·5	+ 2·1	0	− 1·3	− 7·4	−11·1	− 2·4
11 30	− 0·3	+ 1·8	− 0·3	+ 1·0	+ 1·3	0	− 0·8	− 8·3	− 9·1	− 4·6
		3° S. Dec.	6° S. Dec.	9° S. Dec.	12° S. Dec.	15° S. Dec.	18° S. Dec.	21° S. Dec.	24° S. Dec.	27° S. Dec.
30		+ 2·9	+ 4·9	+ 3·2	+ 0·9	0	− 3·1	− 0·1	+ 1·1	− 8·9
1 30		+ 3·7	+ 5·7	+ 3·7	+ 1·8	0	− 3·4	− 0·4	− 2·4	−10·0
2 30		+ 5·1	+ 5·1	+ 4·3	+ 2·0	0	− 2·9	− 3·8	− 4·4	−10·9
3 30		+ 7·5	+ 7·5	+ 3·9	+ 2·8	0	+ 2·4	− 4·4	− 6·8	−11·7
4 30		+ 7·9	+ 5·9	+ 6·3	+ 3·6	0	− 2·2	− 5·4	− 8·2	−13·8
5 30		+ 9·6	+ 7·9	+ 6·9	+ 3·9	0	− 6·3	− 7·1	−12·5	−16·9
6 30		+11·1	+ 8·8	+ 6·3	+ 2·0	0	− 7·4	− 7·3	−10·6	−20·0
7 30		+11·0	+ 6·5	+ 6·7	+ 1·7	0	− 6·8	−12·0	− 1·9	−20·1
8 30		+ 0·5	+ 7·2	+ 3·5	+ 2·6	0	− 4·1	+ 4·7	+ 3·9	−10·2
9 30		+ 6·6	+ 6·6	+ 4·4	+ 1·3	0	− 5·1	+ 1·0	+ 4·9	− 7·8
10 30		− 0·7	+ 2·6	+ 3·6	+ 3·0	0	− 3·3	+ 2·8	+ 4·5	− 7·1
11 30		+ 5·1	+ 2·4	+ 3·4	+ 2·4	0	− 3·0	+ 2·8	+ 0·6	− 9·5

Table XIV.

Showing the Difference in the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Interval corresponding to fifteen degrees Declination, for every three degrees of her Declination north *or* south.

Moon's Transit.	0	3° Dec.	6° Dec.	9° Dec.	12° Dec.	15° Dec.	18° Dec.	21° Dec.	24° Dec.	27° Dec.
h m	m	m	m	m	m	m	m	m	m	m
30	+ 4·8	+ 2·1	+ 2·8	+ 2·2	+ 0·6	0	− 1·6	− 3·8	− 5·1	− 8·1
1 30	+ 3·8	+ 3·5	+ 4·5	+ 3·1	+ 1·7	0	− 2·2	− 3·2	− 6·0	− 8·9
2 30	+ 5·4	+ 4·6	+ 4·8	+ 3·3	+ 2·0	0	− 2·4	− 5·6	− 7·8	−11·0
3 30	+ 6·3	+ 6·3	+ 5·8	+ 6·1	+ 2·6	0	+ 0·4	− 4·6	− 8·2	−10·9
4 30	+ 7·3	+ 5·5	+ 6·1	+ 5·8	+ 3·0	0	− 2·7	− 6·4	− 9·9	−14·4
5 30	+ 8·4	+ 8·9	+ 8·0	+ 6·0	+ 2·1	0	− 5·9	− 8·4	−12·8	−17·1
6 30	+11·3	+10·4	+ 8·3	+ 6·3	+ 2·8	0	− 5·1	− 9·1	−12·8	−19·5
7 30	+ 5·5	+ 7·1	+ 4·9	+ 4·5	+ 0·5	0	− 5·7	−13·3	− 9·6	−18·0
8 30	+ 4·2	+ 1·1	+ 5·5	+ 1·8	+ 2·7	0	− 2·8	− 2·0	− 6·6	− 6·4
9 30	+ 3·7	+ 2·1	+ 3·9	+ 3·4	+ 0·5	0	− 2·4	− 2·9	− 4·5	− 4·6
10 30	+ 3·7	− 1·6	+ 1·6	+ 2·0	+ 2·5	0	− 2·3	− 2·3	− 1·0	− 5·2
11 30	+ 2·3	+ 3·5	+ 1·1	+ 2·2	+ 1·9	0	− 1·9	− 2·7	− 4·2	− 7·0

Table XV. (Interpolated from Table X.)

Showing the Height of High Water at the Liverpool Docks for every three degrees of the Moon's Declination north *and* south.

Moon's Transit.	0° Dec.	3° N. Dec.	6° N. Dec.	9° N. Dec.	12° N. Dec.	15° N. Dec.	18° N. Dec.	21° N. Dec.	24° N. Dec.	27° N. Dec.	Mean.
h m	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
30	18·33	18·30	18·14	18·09	18·00	17·79	17·08	17·80	17·43	16·34	17·73
1 30	18·27	18·31	18·49	18·17	17·86	17·63	17·17	17·44	17·72	16·11	17·72
2 30	17·49	17·90	17·71	17·40	17·39	16·89	16·72	17·16	17·38	15·97	17·20
3 30	16·75	16·38	16·40	16·38	16·04	16·10	15·91	16·14	16·44	15·10	16·14
4 30	15·04	15·17	15·05	14·94	14·87	14·64	14·39	14·91	15·04	13·70	14·77
5 30	14·12	13·61	13·78	13·77	13·53	13·15	12·80	13·37	13·45	12·37	13·40
6 30	13·08	13·13	12·69	12·68	12·38	12·27	11·87	12·21	12·16	10·75	12·32
7 30	12·91	13·24	13·19	12·71	12·56	12·13	12·00	12·19	11·97	10·82	12·97
8 30	14·13	13·86	13·48	14·11	13·63	13·33	13·01	13·32	13·07	12·12	13·41
9 30	15·14	15·52	15·21	15·11	14·92	14·90	14·67	14·53	14·92	13·69	14·86
10 30	16·86	16·71	16·64	16·49	16·22	16·51	15·95	16·19	15·97	15·02	16·26
11 30	16·83	17·69	17·23	17·56	17·25	17·07	16·81	17·00	16·75	15·52	16·97
		3° S. Dec.	6° S. Dec.	9° S. Dec.	12° S. Dec.	15° S. Dec.	18° S. Dec.	21° S. Dec.	24° S. Dec.	27° S. Dec.	
30		18·54	18·00	18·40	18·38	18·19	17·93	17·10	16·41	17·21	17·80
1 30		18·28	18·50	18·41	18·44	18·21	18·20	17·04	16·45	17·46	17·89
2 30		17·60	17·73	17·68	17·67	17·54	17·80	16·41	16·08	16·99	17·03
3 30		16·55	16·68	16·81	16·64	16·40	16·74	15·80	15·45	16·09	16·35
4 30		15·43	15·43	15·20	15·13	15·14	14·87	14·39	13·99	14·64	14·91
5 30		13·75	14·06	13·76	13·89	14·06	13·64	12·74	12·53	13·20	13·51
6 30		12·94	12·86	13·03	12·55	12·64	12·83	11·43	11·22	11·54	12·34
7 30		13·00	12·95	12·54	12·62	12·65	12·65	11·63	11·31	11·57	12·33
8 30		13·13	13·85	13·88	13·67	13·51	13·64	12·62	12·56	12·90	13·31
9 30		15·31	15·48	15·69	15·11	15·09	15·18	14·51	14·14	14·30	14·96
10 30		16·69	16·95	16·63	16·75	16·56	16·49	15·67	15·12	15·45	16·26
11 30		17·73	18·00	18·15	17·58	17·37	17·45	16·57	16·30	16·46	17·29

Table XVI.

Showing the Height of High Water at the Liverpool Docks for every three degrees of the Moon's Declination north *or* south.

Moon's Transit.	0° Dec.	3° Dec.	6° Dec.	9° Dec.	12° Dec.	15° Dec.	18° Dec.	21° Dec.	24° Dec.	27° Dec.	Mean.
h m	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
30	18·33	18·42	18·07	18·24	18·19	17·99	17·50	17·45	16·92	16·77	17·79
1 30	18·27	18·30	18·50	18·29	18·15	17·92	17·69	17·24	17·08	16·79	17·82
2 30	17·49	17·75	17·72	17·54	17·53	17·22	17·26	16·78	16·73	16·49	17·25
3 30	16·75	16·47	16·54	16·60	16·34	16·25	16·33	15·97	15·95	15·60	16·28
4 30	15·04	15·30	15·24	14·98	15·00	14·89	14·53	14·65	14·52	14·17	14·83
5 30	14·12	13·68	13·92	13·76	13·71	13·60	13·22	13·06	12·99	12·78	13·48
6 30	13·08	13·04	12·77	12·86	12·46	12·45	12·35	11·80	11·69	11·15	12·36
7 30	12·91	13·12	13·07	12·62	12·59	12·39	12·32	11·91	11·64	11·19	12·38
8 30	14·13	13·50	13·66	14·00	13·65	13·42	13·33	12·97	12·80	12·51	13·40
9 30	15·14	15·41	15·35	15·40	15·01	15·00	14·93	14·52	14·53	14·00	14·93
10 30	16·86	16·70	16·80	16·56	16·49	16·53	16·22	15·93	15·54	15·24	16·29
11 30	16·83	17·71	17·61	17·86	17·41	17·22	17·13	16·79	16·52	15·99	17·71

Table XVII.

Showing the Difference between the Height of High Water and the Height corresponding to fifteen degrees of the Moon's Declination, for every three degrees of her Declination north *and* south.

Moon's Transit.	0° Dec.	3° N. Dec.	6° N. Dec.	9° N. Dec.	12° N. Dec.	15° N. Dec.	18° N. Dec.	21° N. Dec.	24° N. Dec.	27° N. Dec.
h m	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
30	+·54	+ ·51	+·35	+·30	+·21	0	−·71	+·09	−·36	−1·45
1 30	+·64	+ ·68	+·86	+·54	+·23	0	−·46	−·19	+·09	−1·52
2 30	+·60	+1·01	+·82	+·51	+·50	0	−·17	+·27	+·49	− ·92
3 30	+·65	+ ·28	+·30	+·28	−·06	0	−·19	+·04	+·34	−1·00
4 30	+·40	+ ·53	+·41	+·30	+·23	0	−·25	+·27	+·40	− ·94
5 30	+·97	+ ·46	+·63	+·62	+·38	0	−·35	+·22	+·22	− ·78
6 30	+·81	+ ·86	+·42	+·41	+·11	0	−·40	−·06	−·11	−2·52
7 30	+·78	+ ·11	+·06	+·58	+·47	0	−·13	+·06	−·16	−1·31
8 30	+·80	+ ·53	−·15	+·78	+·30	0	−·32	−·01	−·26	−1·21
9 30	+·24	+ ·62	+·31	+·21	+·02	0	−·23	−·37	+·02	−1·21
10 30	+·35	+ ·20	+·13	−·02	−·29	0	−·56	−·32	−·54	−1·49
11 30	−·24	+ ·62	−·02	+·49	+·18	0	−·26	−·07	−·32	−1·29
		3° S. Dec.	6° S. Dec.	9° S. Dec.	12° S. Dec.	15° S. Dec.	18° S. Dec.	21° S. Dec.	24° S. Dec.	27° S. Dec.
30		+·35	−·19	+·21	+·19	0	−·26	−1·09	−1·78	− ·98
1 30		+·07	−·16	+·20	+·23	0	−·01	−1·17	−1·76	− ·75
2 30		+·06	+·19	+·14	+·13	0	+·26	−1·13	−1·46	− ·55
3 30		+·15	+·28	+·41	+·24	0	+·34	− ·60	− ·90	− ·31
4 30		+·29	+·29	+·06	−·01	0	−·27	− ·75	−1·15	− ·50
5 30		−·31	00	−·30	−·17	0	−·42	−2·32	−1·53	− ·86
6 30		+·30	+·22	+·39	−·10	0	+·19	−1·21	−1·42	−1·10
7 30		+·35	+·30	−·11	−·03	0	00	−1·02	−1·34	−1·08
8 30		−·38	+·34	+·37	+·16	0	+·13	− ·89	− ·95	− ·61
9 30		+·22	+·30	+·60	+·02	0	+·09	− ·60	− ·95	− ·79
10 30		+·13	+·39	+·07	+·19	0	−·07	− ·89	−1·44	−1·11
11 30		+·36	+·63	+·78	+·21	0	+·08	− ·80	−1·07	− ·99

Table XVIII.

Showing the Difference between the Height of High Water and the Height corresponding to fifteen degrees of the Moon's Declination, for every three degrees of her Declination north *or* south.

Moon's Transit.	0° Dec.	3° Dec.	6° Dec.	9° Dec.	12° Dec.	15° Dec.	18° Dec.	21° Dec.	24° Dec.	27° Dec.
h m	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
30	+·44	+·43	+·08	+·25	+·20	0	−·49	−·54	−1·07	−1·22
1 30	+·35	+·38	+·58	+·37	+·23	0	−·23	−·68	− ·84	−1·13
2 30	+·27	+·53	+·50	+·32	+·31	0	+·04	−·44	− ·49	− ·73
3 30	+·50	+·22	+·29	+·35	+·09	0	+·08	−·28	− ·30	− ·65
4 30	+·15	+·41	+·35	+·09	+·11	0	−·36	−·24	− ·37	− ·72
5 30	+·52	+·08	+·32	+·16	+·11	0	−·38	−·54	− ·61	− ·82
6 30	+·63	+·59	+·32	+·41	+·01	0	−·10	−·65	− ·76	−1·30
7 30	+·52	+·73	+·68	+·23	+·20	0	−·07	−·48	− ·75	−1·20
8 30	+·71	+·08	+·24	+·58	+·23	0	−·09	−·45	− ·62	− ·91
9 30	+·14	+·41	+·35	+·40	+·01	0	−·07	−·48	− ·47	−1·00
10 30	+·33	+·17	+·23	+·03	−·04	0	−·31	−·60	− ·99	−1·29
11 30	−·39	+·49	+·39	+·64	+·19	0	−·09	−·43	− ·70	−1·23

Table IV. has been formed on the supposition that Mr. HUTCHINSON'S *clock was regulated according to Apparent Solar Time. The following*

TABLE XIX.

Results from Table I., if Mr. HUTCHINSON'S clock was regulated according to Mean Solar Time, showing the Difference in the Interval between the Mean Solar Time of the Moon's Transit and the Time of High Water, and the Mean Interval, for every month in the year.

Moon's Transit.	January.	February.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
h m	m	m	m	m	m	m	m	m	m	m	m	m
30	−13·3	−13·7	− 6·5	+2·8	+ 3·9	− 3·2	− 8·5	− 3·4	+8·5	+16·7	+16·2	0·0
1 30	−11·2	− 7·3	− 5·6	+0·7	+ 1·6	− 4·8	− 7·7	+ 0·3	+7·3	+15·6	+12·9	− 1·6
2 30	− 7·7	−10·1	− 4·5	−1·1	− 2·2	− 4·7	− 4·3	+ 3·3	+9·2	+12·4	+ 9·5	+ 0·3
3 30	− 4·5	− 9·2	− 7·6	−1·4	− 2·5	− 2·0	+ 0·8	− 0·1	+8·3	+ 9·3	+ 7·6	+ 1·2
4 30	− 1·3	−10·2	−11·2	−8·5	− 2·5	+ 2·4	+ 5·6	+ 3·7	+3·8	+ 6·1	+ 7·2	+ 5·4
5 30	+ 1·2	−11·5	−15·5	−9·8	+ 0·1	+ 8·8	+ 6·5	+ 2·0	−0·8	+ 3·5	+ 9·6	+12·0
6 30	− 1·4	−17·8	−19·1	−8·7	+ 5·0	+12·2	+ 5·9	− 6·3	−3·5	+ 2·8	+14·8	+16·4
7 30	− 8·0	−21·0	−17·4	+0·2	+10·3	+10·4	− 7·0	−10·1	−4·1	+11·5	+22·0	+13·7
8 30	−14·0	−19·5	− 9·8	+1·8	+ 8·8	+ 1·9	− 7·9	− 8·7	+2·2	+17·9	+20·5	+ 7·4
9 30	−15·5	−14·5	− 9·0	+3·6	+ 6·0	− 1·5	− 7·1	− 7·6	+4·9	+17·5	+18·2	+ 1·7
10 30	−15·7	−15·3	− 8·3	+4·2	+ 6·7	− 2·3	− 9·6	− 5·8	+7·2	+18·8	+17·7	+ 2·4
11 30	− 7·6	−15·2	− 7·2	+4·4	+ 3·5	− 3·0	−10·0	− 5·6	+8·1	+17·6	+16·0	− 0·1

Table XIII. has been formed upon the supposition that Mr. HUTCHINSON'S *clock was regulated according to Apparent Solar Time. The following*

TABLE XX.

Results from Table X., if Mr. HUTCHINSON'S clock was regulated according to Mean Solar Time, showing the Difference in the Interval between the Mean Solar Time of the Moon's Transit and the Time of High Water, and the Interval corresponding to fifteen degrees Declination, for every three degrees of her Declination north *and* south.

Moon's Transit.	0	3° N. Dec.	6° N. Dec.	9° N. Dec.	12° N. Dec.	15° N. Dec.	18° N. Dec.	21° N. Dec.	24° N. Dec.	27° N. Dec.
h m	m	m	m	m	m	m	m	m	m	m
30	+ 0·5	− 0·9	− 0·8	− 0·1	− 0·8	0	+ 0·3	− 5·7	−10·0	− 4·3
1 30	− 3·5	− 3·1	− 3·3	− 1·9	− 0·8	0	+ 1·9	− 2·4	− 5·1	− 2·1
2 30	− 3·3	− 2·5	− 1·7	− 2·1	− 0·1	0	+ 3·8	− 1·8	− 3·0	− 1·8
3 30	− 2·4	− 3·2	− 2·0	− 1·6	− 1·3	0	+ 2·3	− 0·4	− 3·3	− 2·4
4 30	+ 0·6	− 2·9	+ 0·8	+ 1·2	+ 0·6	0	− 0·5	− 4·6	− 5·9	− 9·0
5 30	+ 5·6	+ 6·6	+ 6·9	+ 4·9	0	0	− 3·0	− 5·3	−11·6	−14·7
6 30	+12·5	+ 7·4	+10·5	+ 7·7	+ 4·7	0	− 3·8	−11·7	−16·3	−21·0
7 30	+ 8·5	+ 9·9	+ 8·7	+ 6·8	+ 1·3	0	− 7·1	−10·8	−21·2	−20·9
8 30	+10·3	+ 9·4	+10·8	+ 6·3	+ 6·8	0	− 5·1	−13·1	−20·3	−11·4
9 30	+10·2	+ 6·0	+ 8·5	+ 8·1	+ 2·0	0	− 4·3	−10·9	−21·6	− 9·5
10 30	+ 7·3	+ 3·1	+ 4·9	+ 4·2	+ 3·9	0	− 4·0	−11·8	−16·2	−10·2
11 30	+ 1·9	+ 4·3	+ 1·4	+ 2·1	+ 2·7	0	− 2·0	− 9·3	−10·5	− 6·8
		3° S. Dec.	6° S. Dec.	9° S. Dec.	12° S. Dec.	15° S. Dec.	18° S. Dec.	21° S. Dec.	24° S. Dec.	27° S. Dec.
30		− 0·1	+ 2·4	+ 2·0	− 0·5	0	− 2·2	+ 0·7	+ 2·9	− 6·9
1 30		− 4·1	− 0·4	− 1·2	− 1·0	0	− 1·5	+ 3·5	+ 2·1	− 4·7
2 30		− 2·4	− 1·4	− 0·3	− 1·4	0	+ 1·0	+ 2·0	+ 2·4	− 3·8
3 30		− 0·4	− 1·5	− 1·5	− 0·9	0	+ 6·9	− 0·4	− 0·7	−10·3
4 30		+ 0·8	+ 1·7	+ 1·4	+ 1·2	0	+ 1·7	− 1·3	− 3·9	− 6·4
5 30		+ 7·6	+ 5·1	+ 7·1	+ 2·8	0	− 5·3	− 6·0	−10·3	−14·7
6 30		+10·0	+10·9	+ 7·5	+ 3·9	0	− 8·4	− 8·6	−11·3	−13·5
7 30		+16·7	+10·8	+11·6	+ 4·5	0	−10·6	−15·8	− 6·6	−26·9
8 30		+ 7·8	+13·1	+ 8·1	+ 5·7	0	− 7·8	− ·9	− 3·3	−10·4
9 30		+14·1	+13·0	+ 8·1	+ 3·4	0	−10·6	− 4·6	− 2·3	− 6·9
10 30		+ 5·0	+ 7·9	+ 8·2	+ 4·2	0	− 6·4	− 0·9	− 1·1	−13·5
11 30		+ 9·9	+ 4·5	+ 6·1	+ 3·8	0	+ 3·7	+ 1·8	− 0·6	−12·2

Tables to be used in predicting the Time of High Water at Liverpool.

Table XXI.

Showing the Semimenstrual Inequality + a constant, or the Interval between the Moon's Transit and the Time of High Water, her Parallax being 57′, and her Declination 15°. (This Table has been formed by interpolation from the column corresponding to Parallax 57′ in Table VII.)

Moon's Transit.	Interval.	Moon's Transit.	Interval.	Moon's Transit.	Interval.	Moon's Transit.	Interval.	Moon's Transit.	Interval.
h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
0 0	11 25	2 30	10 45	5 0	10 23	7 30	11 16	10 0	11 50
0 10	11 23	2 40	10 43	5 10	10 23	7 40	11 20	10 10	11 49
0 20	11 21	2 50	10 41	5 20	10 23	7 50	11 25	10 20	11 48
0 30	11 18	3 0	10 39	5 30	10 23	8 0	11 30	10 30	11 47
0 40	11 16	3 10	10 37	5 40	10 24	8 10	11 34	10 40	11 44
0 50	11 13	3 20	10 35	5 50	10 26	8 20	11 39	10 50	11 41
1 0	11 10	3 30	10 33	6 0	10 28	8 30	11 44	11 0	11 39
1 10	11 8	3 40	10 32	6 10	10 32	8 40	11 46	11 10	11 37
1 20	11 5	3 50	10 31	6 20	10 36	8 50	11 48	11 20	11 35
1 30	11 2	4 0	10 30	6 30	10 40	9 0	11 50	11 30	11 32
1 40	11 0	4 10	10 28	6 40	10 46	9 10	11 51	11 40	11 30
1 50	10 57	4 20	10 26	6 50	10 52	9 20	11 51	11 50	11 28
2 0	10 54	4 30	10 25	7 0	10 58	9 30	11 52		
2 10	10 51	4 40	10 24	7 10	11 4	9 40	11 52		
2 20	10 48	4 50	10 24	7 20	11 10	9 50	11 51		

Table XXII.

Showing the Semimenstrual Inequality + a constant, or the Height of High Water at Liverpool, the Moon's Parallax being 57′, and her Declination 15°, from the Sill of the Old Dock Gates.

Moon's Transit.	Height of High Water.	Moon's Transit.	Height of High Water.	Moon's Transit.	Height of High Water.	Moon's Transit.	Height of High Water.	Moon's Transit.	Height of High Water.
h m	feet.	h m	feet.	h m	feet.	h m	feet.	h m	feet.
0 0	17·25	2 30	17·04	5 0	14·12	7 30	12·33	10 0	15·40
0 10	17·35	2 40	16·90	5 10	13·90	7 40	12·40	10 10	15·60
0 20	17·45	2 50	16·75	5 20	13·65	7 50	12·55	10 20	15·80
0 30	17·53	3 0	16·60	5 30	13·39	8 0	12·70	10 30	16·00
0 40	17·55	3 10	16·45	5 40	13·21	8 10	12·90	10 40	16·20
0 50	17·57	3 20	16·30	5 50	13·05	8 20	13·10	10 50	16·35
1 0	17·59	3 30	16·17	6 0	12·90	8 30	13·36	11 0	16·50
1 10	17·61	3 40	15·95	6 10	12·77	8 40	13·60	11 10	16·68
1 20	17·62	3 50	15·73	6 20	12·65	8 50	13·80	11 20	16·85
1 30	17·63	4 0	15·51	6 30	12·53	9 0	14·10	11 30	17·00
1 40	17·59	4 10	15·30	6 40	12·44	9 10	14·30	11 40	17·10
1 50	17·50	4 20	15·10	6 50	12·40	9 20	14·55	11 50	17·20
2 0	17·40	4 30	14·89	7 0	12·37	9 30	14·79		
2 10	17·30	4 40	14·60	7 10	12·34	9 40	15·00		
2 20	17·17	4 50	14·37	7 20	12·32	9 50	15·20		

The two following Tables have been made by arbitrary alterations in Tables VIII. and XI., in order to get rid of the irregularities, and may, I think, be considered as showing the effect of changes in the Moon's parallax upon the tides at Liverpool.

Table XXIII.

Showing the Correction for the Moon's Parallax in the Time of High Water at Liverpool.

Moon's Transit.	H. P. 54′.	H. P. 55′.	H. P. 56′.	H. P. 57′.	H. P. 58′.	H. P. 59′.	H. P. 60′.
m	m	m	m	m	m	m	m
0	+ 8	+ 5	+ 2	0	− 2	− 5	− 8
1	+ 7	+ 4	+ 2	0	− 2	− 4	− 7
2	+ 5	+ 3	+ 1	0	− 1	− 3	− 5
3	+ 3	+ 2	+ 1	0	− 1	− 2	− 3
4	+ 2	+ 1	+ 0	0	0	− 1	− 2
5	+ 2	+ 1	+ 0	0	0	− 1	− 2
6	+ 4	+ 2	+ 1	0	− 1	− 2	− 4
7	+ 10	+ 6	+ 3	0	− 3	− 6	− 10
8	+ 15	+ 10	+ 5	0	− 5	− 10	− 15
9	+ 15	+ 10	+ 5	0	− 5	− 10	− 15
10	+ 12	+ 8	+ 4	0	− 4	− 8	− 12
11	+ 10	+ 6	+ 3	0	− 3	− 6	− 10

Table XXIV.

Showing the Correction for the Moon's Parallax in the Height of High Water at Liverpool.

Moon's Transit.	H. P. 54′.	H. P. 55′.	H. P. 56′.	H. P. 57′.	H. P. 58′.	H. P. 59′.	H. P. 60′.
h	feet.	feet.	feet.	feet.	feet.	feet.	feet.
0	−1·15	− ·76	−·38	0	+·38	+ ·76	+1·15
1	−1·25	− ·82	−·41	0	+·41	+ ·82	+1·25
2	−1·40	− ·92	−·46	0	+·46	+ ·92	+1·40
3	−1·50	−1·00	−·50	0	+·50	+1·00	+1·50
4	−1·50	−1·00	−·50	0	+·50	+1·00	+1·50
5	−1·50	−1·00	−·50	0	+·50	+1·00	+1·50
6	−1·50	−1·00	−·50	0	+·50	+1·00	+1·50
7	−1·45	− ·98	−·48	0	+·48	+ ·96	+1·45
8	−1·35	− ·90	−·45	0	+·45	+ ·90	+1·35
9	−1·30	− ·86	−·43	0	+·43	+ ·86	+1·30
10	−1·25	− ·82	−·41	0	+·41	+ ·82	+1·25
11	−1·20	− ·80	−·40	0	+·40	+ ·80	+1·20

The following Table has been formed from Table XIV.

Table XXV.

Showing the Correction for the Moon's Declination in the Time of High Water at Liverpool, *if Mr.* Hutchinson's *Clock was regulated according to Apparent Solar Time.*

Moon's Transit.	0° Dec.	3° Dec.	6° Dec.	9° Dec.	12° Dec.	15° Dec.	18° Dec.	21° Dec.	24° Dec.	27° Dec.
h	m	m	m	m	m	m	m	m	m	m
0	+ 4	+ 3	+ 2	+ 1	+ 1	0	− 1	− 3	− 5	− 7
1	+ 5	+ 4	+ 2	+ 2	+ 1	0	− 2	− 4	− 6	− 8
2	+ 6	+ 4	+ 3	+ 2	+ 1	0	− 2	− 4	− 6	− 9
3	+ 7	+ 5	+ 3	+ 2	+ 1	0	− 2	− 4	− 7	−10
4	+ 9	+ 7	+ 5	+ 3	+ 1	0	− 3	− 6	− 9	−13
5	+11	+ 8	+ 6	+ 4	+ 2	0	− 4	− 8	−12	−16
6	+13	+10	+ 7	+ 4	+ 2	0	− 4	− 8	−13	−18
7	+ 9	+ 7	+ 5	+ 3	+ 1	0	− 4	− 8	−13	−18
8	+ 6	+ 4	+ 3	+ 2	+ 1	0	− 4	− 8	−12	−17
9	+ 4	+ 3	+ 2	+ 1	+ 1	0	− 1	− 3	− 5	− 7
10	+ 3	+ 2	+ 1	+ 1	+ 1	0	− 1	− 2	− 3	− 4
11	+ 3	+ 2	+ 1	+ 1	+ 1	0	− 1	− 2	− 3	− 4

The following Table has been formed from Table XVIII. Although it would seem from Table XVII. that a difference does exist in the correction for north and south declination, yet the numbers in the latter Table are so irregular as almost to defy any attempt to reduce them to uniformity.

Table XXVI.

Showing the Correction for the Moon's Declination in the Height of High Water at Liverpool.

Moon's Transit.	0° Dec.	3° Dec.	6° Dec.	9° Dec.	12° Dec.	15° Dec.	18° Dec.	21° Dec.	24° Dec.	29° Dec.
h	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
0	+·40	+·32	+·24	+·16	+·08	0	−·25	−·50	−·75	−1·00
1	+·55	+·44	+·33	+·22	+·11	0	−·25	−·50	−·75	−1·00
2	+·64	+·52	+·39	+·26	+·13	0	−·19	−·37	−·56	−·75
3	+·60	+·48	+·36	+·24	+·12	0	−·12	−·25	−·37	−·50
4	+·40	+·32	+·24	+·16	+·08	0	−·10	−·20	−·30	−·40
5	+·38	+·29	+·21	+·14	+·07	0	−·16	−·32	−·48	−·65
6	+·50	+·40	+·30	+·20	+·10	0	−·21	−·42	−·63	−·85
7	+·70	+·56	+·42	+·28	+·14	0	−·22	−·44	−·66	−·90
8	+·60	+·48	+·36	+·24	+·12	0	−·20	−·40	−·60	−·80
9	+·50	+·40	+·30	+·20	+·10	0	−·14	−·28	−·42	−·55
10	+·40	+·32	+·24	+·16	+·08	0	−·14	−·28	−·42	−·55
11	+·30	+·24	+·18	+·12	+·06	0	−·17	−·34	−·51	−·70

Index to the Tables formed from Mr. HUTCHINSON'S *Observations.*

In forming these Tables it has been assumed that the Observations were recorded in Apparent Solar Time. The Time of the Moon's Transit at Greenwich, which constitutes the principal argument of the Tables, is always given in Apparent Solar Time.

Table I., showing the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Height of High Water at the Liverpool Old Docks (as recorded by Mr. HUTCHINSON), corresponding to the Apparent Solar Time of the Moon's Transit, in each month of the year. (If Mr. HUTCHINSON'S clock was regulated according to *mean* solar time, the interval must be *diminished* by the equation of time given at foot of each month.)

Table II. (Interpolated from Table I.), showing the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water at Liverpool Old Docks, for each month in the year.

Table III. (Interpolated from Table I.), showing the Height of High Water at Liverpool Old Docks, corresponding to the Apparent Solar Time of the Moon's Transit, in each month of the year.

Table IV., showing the Difference in the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Mean Interval, for every month in the year.

Table V., showing the Difference in the Height of High Water and the Mean Height for every month in the year.

Table VI., showing the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Height of High Water at the Liverpool Old Docks, corresponding to the Apparent Solar Time of the Moon's Transit, for every minute of her Horizontal Parallax.

Table VII. (Interpolated from Table VI.)

Table VIII., showing the Difference in the Interval between the Time of the Moon's Transit and the Time of High Water, and the Interval corresponding to fifty-seven minutes of the Moon's Horizontal Parallax.

Table IX., showing the Difference between the Height of High Water and the Height corresponding to fifty-seven minutes of the Moon's Horizontal Parallax.

Table X., showing the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Height of High Water at the Liverpool Old Docks, corresponding to the Apparent Solar Time of the Moon's Transit, for every three degrees of her Declination north and south. The Equation of Time to be added to Apparent Time. (In forming this Table, it has been assumed that Mr. HUTCHINSON'S clock was regulated according to *apparent* solar time; if it was regulated according to *mean* solar time, the interval must be *diminished* by the equation of time given in the third column.)

Table XI. (Interpolated from Table X.), showing the Interval between the Apparent Time of the Moon's Transit and the Time of High Water at the Liverpool Old Docks for every three degrees of her Declination north *and* south.

Table XII., showing the Interval between the Apparent Time of the Moon's Transit and the Time of High Water at the Liverpool Old Docks for every three degrees of her Declination north *or* south.

Table XIII., showing the Difference in the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Interval corresponding to 15° Declination, for every three degrees of her Declination north *and* south.

Table XIV., showing the Difference in the Interval between the Apparent Solar Time of the Moon's Transit and the Time of High Water, and the Interval corresponding to 15° Declination, for every three degrees of her Declination north *or* south.

Table XV. (Interpolated from Table X.), showing the Height of High Water at the Liverpool Docks for every three degrees of the Moon's Declination north *and* south.

Table XVI., showing the Height of High Water at the Liverpool Docks for every three degrees of the Moon's Declination north *or* south.

Table XVII., showing the Difference between the Height of High Water and the Height corresponding to fifteen degrees of the Moon's Declination, for every three degrees of her Declination north *and* south.

Table XVIII., showing the Difference between the Height of High Water and the Height corresponding to fifteen degrees of the Moon's Declination, for every three degrees of her Declination north *or* south.

Table XIX. results from Table I., if Mr. Hutchinson's Clock was regulated according to Mean Solar Time, showing the Difference in the Interval between the Mean Solar Time of the Moon's Transit and the Time of High Water, and the Mean Interval, for every month in the year.

Table XX. results from Table X., if Mr. Hutchinson's Clock was regulated according to Mean Solar Time, showing the Difference in the Interval between the Mean Solar Time of the Moon's Transit and the Time of High Water, and the Interval corresponding to 15° Declination, for every three degrees of her Declination north *and* south.

Table XXI., showing the Semimenstrual Inequality + a constant, or the Interval between the Moon's Transit and the Time of High Water, her Parallax being 57′, and her Declination 15°. (This Table has been formed by interpolation from the column corresponding to Parallax 57′ in Table VII.)

Table XXII., showing the Semimenstrual Inequality + a constant, or the Height of High Water at Liverpool, the Moon's Parallax being 57′, and her Declination 15°, from the Sill of the Old Dock Gates.

Table XXIII., showing the correction for the Moon's Parallax in the Time of High Water at Liverpool.

Table XXIV., showing the Correction for the Moon's Parallax in the Height of High Water at Liverpool.

Table XXV., showing the Correction for the Moon's Declination in the Time of High Water at Liverpool, *if Mr.* HUTCHINSON'S *Clock was regulated according to Apparent Solar Time.*

Table XXVI., showing the Correction for the Moon's Declination in the Height of High Water at Liverpool.

XVI. *Remarks on the difficulty of distinguishing certain Genera of Testaceous* Mollusca *by their Shells alone, and on the Anomalies in regard to Habitation observed in certain Species.* *By* JOHN EDWARD GRAY, *Esq. F.R.S. &c.*

Received June 11,—Read June 18, 1835.

IT has been a very common error, both among conchologists and geologists, to regard all shells in which no remarkable difference of form and character can be distinguished as inhabited by one and the same genus of animals; and not less usual to assume that all the species of the same genus inhabit similar localities. Many geologists have still further enlarged the boundaries of error, by taking for granted that all the fossil species of shells which are referrible by the characters of the shell to recent genera, must have been formed by animals which, in their recent state, possessed the same habits as the most commonly observed species of the genus to which they appear to belong. These theories were, indeed, quite consistent with our former ignorance of the habits of the animals of this class; but since the works of POLI, MÜLLER, MONTAGU, LAMARCK, and CUVIER have induced zoologists again to turn their attention, as was the practice among the older writers, to the animals of shells, and their habits, and no longer to confine themselves, as was too often the case with the followers of the Linnean system of conchology, to the study of the shells as mere pieces of ornament, classed without reference to their inhabitants, the acknowledged importance of the subject is daily bringing to our knowledge some animal unknown before, and adding to our stock of information facts which prove the fallacy of the opinions so hastily taken up. Thus, although even at the present day the animals of less than one twentieth part of the well-known species of shells have been observed, —and of those which are known the greater part have been very imperfectly described,—numerous exceptions to the theories in question have been brought to light, which deserve to be collected into one point of view, and made the subject of serious consideration.

The exceptions which it is the object of the present paper to notice may be arranged under the two following heads:

1. Shells having every appearance of belonging to the same natural genus, but inhabited by animals of a very different character.

2. Species of testaceous *Mollusca* living in very different situations from the majority of the known species of the genus to which they belong, or having the faculty of maintaining their existence in several different situations.

These two classes of exceptions I shall proceed to notice in detail.

1. *Of Shells apparently similar, but belonging, on a comparison of their Animals, to very different Genera.*

In a note on my former paper on the structure of shells *, I pointed out the perplexity in which the extreme similarity of the shells belonging to the genera *Patella* and *Lottia* must involve the geologist and the conchologist, intending at some future time to pursue the subject further, and to show that similar difficulties existed in regard to several other genera. The two genera above referred to are probably, however, the most remarkable example of this complete resemblance, on account of the extreme dissimilarity of their animals, which are referrible to two very different orders of *Mollusca*, while the shells are so perfectly alike, that after a long-continued study of numerous species of each genus, I cannot find any character by which they can be distinguished with any degree of certainty. Both genera present a striking discrepancy from all other univalve shells, in having the apex of the shell turned towards the head of the animal, the genera to which they are immediately related in both the orders to which they belong offering no variation in this respect from the usual structure of the class. The agreement in the internal structure of their shells is equally complete; yet the animal of *Patella* has the branchiæ in the form of a series of small plates disposed in a circle round the inner edge of the mantle, while that of *Lottia* has a triangular pectinated gill seated in a proper cavity formed over the back of the neck within the mantle, agreeing in this respect with the inhabitants of the *Trochi*, *Monodontæ*, and *Turbines*, from which it differs so remarkably in the simple conical form of its shell. This difference in the respiratory organs of animals inhabiting shells so strikingly similar is the more anomalous, inasmuch as those organs commonly exercise great influence on the general form of shells; a circumstance readily accounted for when we reflect that a principal object of the shell is to afford protection to those delicate and highly important parts.

To the practical conchologist it will be sufficient to mention *Pupa* and *Vertigo*, *Vitrina* and *Nanina*, *Rissoa* and *Truncatella*, as affording numerous and perplexing instances of the difficulty of distinguishing between genera of shells, inhabited by very different animals.

A similar difficulty exists with regard to *Siphonaria* and *Ancylus*, genera belonging to two different families, one inhabiting the sea-shores, while the other lives in rivers and brooks. The only distinction between the shells of these two genera consists in the *Ancyli* being generally of a thinner substance than the *Siphonariæ*; but this is by no means an adequate character, some species of *Siphonaria* (*S. Tristensis*, for example,) being quite as thin in texture as any *Ancylus*. Both have the muscular impression interrupted by the canal through which the air passes to the respiratory organs; yet the animal of *Ancylus* has long tentacles, and eyes placed as in the *Lymnææ*, to which it is closely allied, while *Siphonaria* has no distinct tentacles, and

* Philosophical Transactions, 1834, p. 800.

in these respects agrees with the equally marine genus *Amphibola*, confounded by Lamarck with the *Ampullariæ*.

About fifteen years since, I first observed, in the marshes near the banks of the Thames between Greenwich and Woolwich, in company with species of *Valvata*, *Bithynia*, and *Pisidium*, a small univalve shell, agreeing with the smaller species of the littoral genus *Littorina* in every character both of shell and operculum; yet this very peculiar and apparently local species has an animal which at once distinguishes it from the animal of that genus, and from all other Ctenobranchous *Mollusca*. Its tentacles are very short and thick, and have the eyes placed at their tips; while the *Littorinæ*, and all the other animals of the order to which they belong, have their eyes placed on small tubercles on the outer side of the base of the tentacles, which are generally more or less elongated. The shell in question and its animal were described and figured by Dr. Leach, in his hitherto unpublished work on British *Mollusca*, under the name of *Assiminia Grayana*; and as this name has been referred to by Mr. Jeffries and other conchologists, it may be regarded as established, and that of *Syncera hepatica*, proposed by myself in the Medical Repository, vol. x. p. 239, will take the rank of a synonym. A second species of this genus has lately been made known by Mr. Benson, by whom it was found in ponds in India. Its shell is banded like that of *Littorina 4-fasciata* and several others of the smaller *Littorinæ*, and had been figured in the Supplement to Wood's Catalogue, t. 6. f. 28, under the name of *Turbo Francesiæ*.

Taking this in conjunction with the preceding, we have here two instances of univalve shells apparently belonging to the same genus, the one found in fresh and the other in salt water, but proving, when their animals are examined, to belong to genera essentially distinct. My next illustration will show that a similar fact has been observed among the bivalves.

The *Mytilus polymorphus* of Chemnitz is truly a freshwater species, having been first observed in the Wolga by the illustrious Pallas. It has recently been introduced, doubtless with the Russian timber, (for this species, in common with the *Ampullariæ*, *Paludinæ*, and *Neritinæ* of fresh water, and the *Littorinæ*, *Monodontæ*, and *Cerithia* of salt, has the faculty of living for a very long time out of water,) into the Lake of Haarlem and the Commercial Docks at Rotherhithe; in both of which it appears to increase with great rapidity. I am aware that Mr. Lyell has given another explanation of the mode of introduction of this remarkable species; but from experiments which I have myself made on the animal's power of living out of water, I cannot hesitate in giving the preference to the suggestion advanced above, rather than supposing it to have made its passage from one river to the other, across the sea, attached to the bottom of a vessel. The shell in question differs from the shells of other *Mytili* in no character of more than specific importance; but the animal is essentially distinct. In the genus *Mytilus* the lobes of the mantle are free throughout nearly their whole circumference, as in *Unio*, *Cardita*, *Pecten*, *Ostrea*, &c.; while in

the animal of *Mytilus polymorphus* they are united through nearly their whole extent, leaving only three small apertures, one for the passage of the foot and beard, and the other two for the reception and rejection of the water, from the contents of which the animal derives its sustenance. This shell must consequently form a new genus, to which the name of *Dreissena* has been appropriated by Van Beneden *. As a proof of the importance attached to this character, it may be observed that Cuvier considered the adherence or non-adherence of the lobes of the mantle so essential a distinction as to found on it his division of the bivalves into families. In his system, therefore, the genus *Dreissena* would be placed with the family of *Chamacées*, while the genus *Mytilus* forms the type of the preceding family of *Mytilacées*. The genus *Iridina*, however, and one or two others, show that this character cannot be implicitly relied on for the natural classification of animals of this class, although it forms a very good generic mark of distinction.

The genus *Iridina* † above referred to affords a second instance of this anomaly; for though the animals of the *Iridinæ* and *Anodontæ* differ in the adhesion and non-adhesion of the lobes of the mantles, yet the shells are so alike that they cannot be distinguished by any external character; so much so, that one of the species now referred to the genus by M. Deshayes, who first pointed out this peculiarity in the animal, was considered as an *Anodon* by Lamarck.

The animals of *Cytherea*, *Venus*, and *Venerupis* have, like those of most of the allied genera, a lanceolate foot projecting at the anterior part of the shell; while the genus *Artemis* of Poli, which has generally been confounded with *Cytherea*, from which it is not easily to be distinguished except by its usually more rounded form, is provided with a crescent-shaped foot, exserted at the middle of the lower edges of the valves.

Again, there is but little difference in external characters and habit between *Cyclas* and *Pisidium*; but the animals of the latter have elongated siphons which are not found in the former.

In reference to Univalves it may also be observed, that it is frequently impossible to distinguish some of the genera of that class without an examination of their opercula. This is the case, for instance, as regards the smaller and more solid *Paludinæ*, inhabitants of fresh water, and some species of *Littorina* living on the coast; several of the shells described as *Paludinæ* by Draparnauld and others appearing rather to belong to the latter genus. A similar difficulty exists with respect to other *Littorinæ* as distinguished from *Phasianella*, and with the *Neritinæ* as distinguished from the *Neritæ*. In the latter case the characters derived from the operculum are so essential

* Institut, 1835, p. 130; and Annales des Sciences Naturelles, N. S., tom. iii. p. 193.

† Lamarck formed this genus on a specimen which had its hinge margin accidentally tubercular and slightly crenated; but this character is not found in most of the specimens of the species which he describes. The English conchologists, misled by this character, have referred to the genus a very different African shell, with a long series of transverse teeth on the hinge margin, which has lately been separated by Mr. Conrad under the name of *Pleiodon*.

to the discrimination of the two genera, that M. Rang, looking only to the characters of the shell, has proposed to reunite them into one. In proof of the little attention that has hitherto been paid to this very important part, I may mention that three species referred by Lamarck to the genus *Solarium* are each furnished with a different kind of operculum; and it is deserving of notice that the *Monodonta canaliculata*, according to the observations of M. Quoy, has an operculum very different from the rest of the shells of that genus.

In some shells, again, the differences in character are so slight as almost to throw an air of ridicule on the attempt to separate them generically from the structure of the shells alone; and yet when the animal is examined the necessity of their separation becomes so obvious as to be immediately acknowledged. This is especially the case with my genus *Bullia* compared with *Terebra*: the shells of these two genera are so similar, that Lamarck and all other conchologists have retained them in one group, no other distinction being observable except that in the former there is a more or less distinct callous band winding round the volutions just above the suture, and produced by a slight extension of the inner lip beyond the part of the shell occupied by the whorl. This extension of the lip is probably deposited by the foot of the animal, which in the genus *Bullia* is very large and expanded, while that of *Terebra* is small and compressed. This, however, is not the only difference between the two animals, that of the former genus having rather large and eyeless tentacles, while the *Terebræ* have very small and short tentacles, bearing the eyes near their tips.

A second example of a similar kind is derived from the genus *Rostellaria*, in which Lamarck includes the *Strombus Pes Pelecani* of Linnæus. The animal of this shell has been figured by Müller, and very much resembles that of *Buccinum*, having long slender tentacles with the eyes sessile on the outer side of their base; while, as Dr. Rüppell informs me, the *Rostellaria curvirostris* has an animal allied to *Strombus*, with the eyes on very large peduncles, which give off from the middle of one of their sides the small tentacles. Notwithstanding this difference in the form of their animals, I am not, however, aware of any essential character by which the shell of *Aporrhais* (as the *Strombus Pes Pelecani* has been generically named) can be distinguished from the other *Rostellariæ*.

With all this uncertainty with regard to the generic characters of the recent species of shells, of which the animals can be subjected to examination, how much must the difficulty of deciding their genera with certainty be enhanced with reference to the fossil species, and especially to those which have no strictly analogous form existing in the recent state. Considerations like these tend greatly to disturb the confidence formerly reposed in the opinion that every difference in the form and structure of the animal was accompanied by marks permanently traced upon the shell, by which it might be at once distinguished, and which it was therefore the great object of the conchologist to point out. But another source of error, particularly interesting to the geologist, is included under my second head, to the elucidation of which I shall now proceed.

2. *Of Species belonging to the same natural Genus, inhabiting essentially different situations.*

The general belief that all the species of the same genus inhabit the same kind of situation, undoubtedly holds good with reference to most of the genera of shells; but many exceptions have already been observed, and we may anticipate that many more will be discovered as the natural habits of the different species become better known. In bringing together a number of these exceptions, I have been under the necessity of placing considerable reliance on the observations of others, who have noted in foreign countries facts similar to those which I have myself witnessed at home; but these observations have been chiefly collected from the works of Professor Nilsson of Sweden, of Mr. Say of the United States of North America, and of MM. Lesson, Quoy, and Rang of Paris, writers who, from their extensive knowledge of conchology, are fully capable of accurately recording their observations, and whose statements may therefore be received as deserving of the most implicit confidence. It is moreover to be observed, that all their observations on this subject were made simply with the view of extending the knowledge of the history of the species to which they refer, and without reference to the establishment of any preconceived theory.

These observations may be classed under the four following subdivisions: 1st, where species of the same genus are found in more than one kind of situation, as on land, in fresh and in salt water; 2nd, where one or more species of a genus, most of whose species inhabit fresh water, are found in salt or brackish water; 3rd, where, on the contrary, one or more species of a genus, whose species generally inhabit the sea, are found in fresh water; and 4th, where the same species is found both in salt and fresh water.

Of the first of these classes the genus *Auricula*, as defined by Lamarck, may be quoted as a striking example. Of its species, *A. Scarabus* and *A. minima* are found in damp places on the surface of the earth; *A. Judæ* lives in sandy places overflowed by the sea; *A. Myosotis*, *A. coniformis*, *A. nitens*, &c. (separated by De Montfort under the name of *Conovulus*,) are found only in the sea in company with Chitons, *Littorinæ*, and other truly marine shells; and the South American species which I distinguished some time since under the name of *Chilina*, including *A. Dombeyi* of Lamarck, and *A. fluviatilis* of Lesson, inhabit freshwater streams, having most of the habits of the *Lymnææ*. This disparity of habitation has been in some degree overcome by dividing the genus into several, as noticed above; but the characters employed for their distinction are very slight, and species apparently intermediate between them are constantly occurring.

The genus *Lymnæa* has usually been considered as confined to fresh water; but M. Nilsson describes a species under the name of *L. Balthica*, which is found "in aquâ parùm salsâ Maris Balthici ad littora Gothlandiæ et Scaniæ, &c. In maris juxta Esperöd fucis et lapidibus adhærens frequenter obvenit simul cum *Paludinâ Balthicâ* et *Neritinâ fluviatili*;" and a second under the name of *Lymnæa succinea*, which is

found on the shores of the sea near Trelleborg. All the species of *Paludina* and *Bithynia* which have fallen under my own observation are essentially fluviatile; but M. Nilsson refers in the paragraph above quoted to a species of the former genus inhabiting the sea. This may, however, like some of the smaller *Paludinæ* of Draparnauld, be truly a *Littorina*, having a horny and spiral, and not an annular, operculum.

According to the observations of my sister, Mrs. Ince, of Mr. Benson, of MM. Quoy and Gaimard, and of M. Lesson, the Indian species of *Neritina*, like the European, are found only in fresh water; yet M. Rang, in his Manuel des Mollusques, p. 193, states that the *Neritina viridis* is a marine species found on rocks covered by the sea at Martinique, and that a larger variety of this species is found in similar situations at Madagascar; General Hardwicke marks on his drawing of the *Neritina crepidularis*, that it was found in "saltwater lakes, April 1816;" and Say has described the *Neritina Meleagris* of Lamarck (*Theodoxus reclinatus*, Say,) as living both in fresh and salt water. This is most probably the species to which Mr. Guilding refers*, when he observes that he has kept *Neritina* for some time alive in a close vessel of salt water, which they appear to purify. The animals of some of the tropical species often quit the stream and crawl up the trunks of neighbouring trees, on which, like the species of *Littorina*, *Planaxis*, and *Bulla*, which creep up the rocks on the sea-coast, they attach themselves, and remain exposed to the influence of the sun. It may be added, that M. Rang has found *Neritina Auricula* in brackish marshes near the sea in the Island of Bourbon, in company with *Aviculæ* and *Aplysiæ*; and I have little doubt that *Neritina Pupa* inhabits the sea, it being uniformly brought to this country in company with marine shells.

Many species of *Melania*, as, for example, *M. amarula*, *M. fasciolata*, and *M. lineata*, are found in the freshwater streams of India and its islands. Mr. Say mentions species found in similar situations in North America; he also describes one (*M. simplex*) as found in a stream running through the saltwater valley near the salt-works, but does not state whether the water of the stream is salt or fresh. On the other hand, M. Quoy asserts that they are sometimes taken in brackish water; M. Cailliaud states that *Melania Oweni* is found in brackish water; and M. Rang has found other species in the Island of Bourbon under the same circumstances with the *Neritina* just adverted to. The genus *Melanopsis* has the same habits; its species are often found in large inland lakes. I have myself received *M. buccinoidea* from the sea of Galilee; and Dr. Clark, in his Travels, vol. ii. p. 243, figures *M. Dufourii* under the name of *Buccinum Galileum*. The water of this lake, however, unlike that of the neighbouring Dead Sea, is, according to the statement of Fuller, perfectly fresh and sweet. M. Lesson, on the other hand, states that he found the *Pyrena terebrans*, regarded by M. de Férussac as a *Melanopsis*, in great abundance in brackish marshes in New Guinea, and at the Island of Bourou.

I am informed by Mr. Sowerby that some species of the fluviatile genus *Cyrena* are found in the sea on the coast of South America; but he thinks it probable that

* See Zoological Journal, vol. v. p. 33.

the part of the sea in which they are met with may be fresh, like certain parts of the ocean described by Dr. Abel in his voyage to China. It would be highly interesting to procure a verification of this observation. Similar phenomena may not be uncommon, for I have myself observed in Torbay a small space in the neighbourhood of Brixham, the water of which was of a different colour and much fresher than that of other parts of the bay. With reference to another species of the same genus, *Cyrena Vanikorensis*, M. Quoy observes: "Ne l'ayant pas trouvée dans les lieux marécageux, mais sur les bords de la mer, il est probable qu'elle vit à l'embouchûre des rivières qui sont saumâtres à marée haute*."

The third class of cases, in which species of *Mollusca* that are generally found in the sea are taken in fresh water, is much more rare than the preceding. It is obvious that in such instances the animal must be possessed of the capability of adapting itself to the different characters of the two fluids. This capability exists in much more highly organized animals, such as fishes, many species of which constantly migrate from the sea and ascend the rivers to deposit their spawn; but in these cases it is the result of a regular and determinate habit, while in the *Mollusca* it appears to be entirely dependent on accidental circumstances.

In some marshes in the Island of Bourbon, in which the water is almost fresh, M. Rang has observed specimens of *Aplysia dolabrifera* in company with *Neritinæ* and *Melaniæ*.

The greater number of species of the genus *Cerithium* are truly marine, chiefly living in sandy bays, like our own *Cerithium reticulatum*. M. Lesson, however, found *C. sulcatum*, and Adanson the African species figured by him, in the pools of brackish water, sometimes overflowed by the sea, which are situated between the weeds and the belts of mangrove trees on the shore; and Mr. Say observes that the small species, called by him *Pyrena scalariformis*, but which is a true *Cerithium*, is found in great abundance in the fresh water of Florida Keys. He adds: "it is most certainly a freshwater shell, yet it is destitute of an epidermis."

The genus *Bulla* is also truly marine; but the Rev. Mr. Hennah some time since presented to the British Museum specimens of one of its species, resembling the *Bulla Hydatis*, found by him in brackish pools on the coast of Chili; and Mr. Say has described a *Bulla fluviatilis* found by Mr. Aaron Stone deeply imbedded in the mud of the river Delaware†.

The *Littorinæ*, again, are all found either on the sea-shore or in the very brackish water of the mouths of rivers, except two, which although described as *Paludinæ* by Pfeiffer and De Férussac, and formed into a distinct genus by Ziegler under the name of *Lithoglyphus*, agree with *Littorina* in every character of shell and operculum, and, as far as I can ascertain from the descriptions, of the animal also. These are the *Paludina fusca* of Pfeiffer, and the *P. naticoides* of De Férussac: they are truly fluviatile.

* Voyage de l'Astrolabe, tom. iii. p. 516.

† See for this latter instance the Journal of the Academy of Natural Sciences of Philadelphia, vol. ii. p. 179.

These anomalies are not restricted to the univalves: bivalves have also their share. Thus, the genus *Solen* is generally and properly considered as marine; but Mr. Benson has lately discovered a species inhabiting the mud on the banks of the Ganges; and conceiving, from the nature of its habitation, that it ought to be separated from the common species, he has formed a genus for its reception under the name of *Novaculina*. On comparing, however, some specimens of the shell presented to the British Museum by Mr. Royle, I can scarcely distinguish it as a species from the *Solen Dombeyi* of Lamarck, which is found on the coast of Peru; and I have two other species, very nearly related, one from the rivers of China, and the other from pools of brackish water on the coast of America. In like manner M. Nilsson has found his *Tellina Balthica*, which appears to be little more than a variety of the *Tellina solidula* of our coast, in the brackish water of the shores of the Baltic. *Avicula margaritifera*, the mother-of-pearl shell, commonly found in the ocean, has been taken by M. Rang in marshes in the Isle of Bourbon in the neighbourhood of the sea in which the water is nearly fresh. Specimens of *Mya arenaria* also are often found so high up the rivers that the water in which they live is brackish only during high tides. They are found, moreover, with freshwater shells on the coasts of the Baltic, while all the other species of the genus are found only where the water is quite salt.

By far the greater part of the species of *Corbulæ* are truly marine; but there is a large species of the genus, called by Dr. Maton* *Mya labiata*, brought with freshwater shells from the mouth of the Rio de la Plata; and this agrees in many respects with the fossil *Corbula Gallica*, which occurs in what are called the upper freshwater strata of the Isle of Wight.

The transitions to which the oysters intended for the London market are exposed may be mentioned as an additional illustration. Many of these are collected in the sea on the coasts of Guernsey and of France, and are brought to situations in the mouth of the river where the water is merely brackish during the ebb of the tide, and where they are consequently subjected to the alternate action of salt and brackish water twice in each day. It is even affirmed that oysters can exist in water absolutely fresh; for in the Museum of the Bristol Institution there is a large group said to have been dredged up in a river on the coast of Africa where the stream was so sweet as to have been used to water the ship. To these shells are attached specimens of *Cerithium armatum*; and the person by whom they were presented to the collection stated that *Cardium ringens* was found abundantly in the same situation.

The genus *Cucullæa*, again, is universally considered as truly marine; but Mr. Benson has found in the Ganges a small shell belonging to it, regarded by him as an *Arca*, but on account of its freshwater origin formed into a new genus under the name of *Scaphula*.

On this subject I may observe, that I was some time ago informed that *Arca senilis* was found in the rivers of Africa in company with *Galatea radiata*: M. Cailliaud,

* Linnean Transactions, vol. x. p. 326, t. 24, f. 3.

however, assures me that this is by no means the case, the shells in question being found near the mouths of the rivers, but never in the rivers themselves.

One of the most decisive facts regarding the finding of the same species of shell in both salt and fresh water is noticed by Say*. Speaking of *Theodoxus reclinatus*, he observes, "I found this species in great plenty, inhabiting St. John's river in East Florida, from its mouth to Fort Picolata, a distance of one hundred miles, where the water is potable. It seemed to exist equally well where the water was as salt as that of the ocean, and where the intermixture of that condiment could not be detected by the taste." The shell in question is determined, by specimens which I received from my late friend himself, (to whom science is so deeply indebted, and especially for his researches into the zoology of North America,) to be the *Neritina Meleagris*, obtained in such abundance from the West Indian Islands. Nilsson too, as before mentioned, has noticed the *Neritina fluviatilis*, which in this country is not observed to inhabit ditches in the neighbourhood even of brackish water, living on the coasts of the Baltic, in brackish situations, in company with *Lymnæa Balthica* and *L. succinea*; and M. Rang found *Neritina auriculata* in similar situations.

According to the observations of Olivier, the *Ampullaria ovata* inhabits Lake Mareotis, where it is taken in company with marine shells found also in the Mediterranean; and I have lately received (dead) specimens from the locality indicated. The same species was found by M. Cailliaud in freshwater lakes in the Oasis of Siwah, where it is called Bozue and eaten as food. It thus appears to be found both in fresh and brackish water. Two of the species referred to this genus by Lamarck, his *Ampullaria Avellana* and *A. fragilis*, are truly marine; but they differ from the others in animal and operculum, as well as in the sinuated form of the outer lip of their shell.

The common cockle of the shops, *Cardium edule*, is constantly to be seen in the ditches of brackish water in the neighbourhood of Tilbury Fort, which gradually become more or less fresh in proportion to the quantity of rain that falls between the periods of opening the sluices. It is to be observed that the specimens found in this situation are rather thinner and more produced posteriorly than those usually found in the sea. The species in question is also, according to Nilsson, found in the brackish water on the shores of the Baltic, but I am not aware whether or not it is there subject to a similar variation in form. Nilsson observes, however, that the marine species found in those localities are generally smaller than those found in other situations.

From this list of exceptions to the general rules which have commonly been regarded as decisive of the localities inhabited by recent shells, and of the nature of the deposits in which the fossil species are found, it is manifest that those rules cannot safely be made use of for practical purposes without considerable reservation.

* Journal of the Academy of Natural Sciences of Philadelphia, vol. ii. p. 258.

XVII. *On the supposed existence of Metamorphoses in the* Crustacea. *By* J. O. Westwood, *F.L.S. & Sec. Ent. Soc. Communicated by* J. G. Children, *Esq., Sec. R.S.*

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PERHAPS none of the phenomena of natural history have attracted a greater share of the attention of mankind in all ages than those exhibited by insects in their passage to the perfect state, and to which it is not surprising that the name of metamorphoses should have been applied. If this were the case in the darker days of zoological knowledge, when the true nature of these changes was not understood, it is not strange that the subject should have lost none of its interest when, owing to the admirable researches of Redi and Swammerdam, De Geer and Reaumur, all of the marvellous has been removed, and a series of gradual developments exposed, far exceeding in peculiarity those exhibited in any of the other tribes of animals.

It will not perhaps be considered out of place if we here shortly glance at those general principles which regulate these metamorphoses amongst the *Annulosa*. "Si nous voulons concevoir," observes Latreille, "d'une manière claire et positive le sens qu'il faut attacher au mot de *métamorphose*, il est necessaire que nous nous formions une idée exacte de celui de *mue*; car leurs significations paraissent avoir beaucoup d'affinité, et il est essentiel de les déterminer aussi rigoureusement qu'il est possible*."

It would, however, lead us to far too great a length were we at the outset to enter into the question of the *gradual formation* of the various organs of annulose animals from the rete mucosum, as insisted upon by Dr. Heroldt in opposition to the generally received opinion of Swammerdam, that these various organs are, from the first exclusion of the insect from the egg, in a state of existence, but enveloped in various coverings which are successively cast off; although the determination of this question must be considered as having a material influence upon the subject under consideration, more especially as it seems difficult to account for the reproduction of the limbs of the *Crustacea* when torn off if we do not adopt the theory of Dr. Heroldt.

Every animated being in its passage to the perfect development of its species undergoes a certain but varied series of changes. In man and most of the vertebrated animals there is a gradual action of the vital forces in different organs till they are fitted for reproduction, accompanied, as progress is made to the adult state, by the acquisition of various appendages, as teeth, horns, pubes, feathers, &c. In addition

* Cours d'Entomologie, p. 271.

to this gradual action, the greater portion of the *Vertebrata* are subject to that particular species of ecdysis which Mr. MacLeay has termed *incomplete*, consisting simply in the integuments, hairs, skin, feathers, &c., scaling off piece by piece, or one by one, as distinguished from that *complete* change in the identity of the envelope of other less perfect animals which prevails in various degrees amongst the *Annulosa* and some few of the *Vertebrata*, and by means of which the entire envelope of the animal is shed at once. And here we may be allowed to notice the rationale of this complete shedding of the envelope which so peculiarly distinguishes the *Annulosa*. In them we find the internal vertebræ of the higher animals converted into a hard horny or crustaceous external covering, to the inner surface of which the muscles are attached. This covering would of course, from its very nature, offer an insurmountable obstacle against the growth of the animal, were it persistent. It is therefore necessary that, in order to ensure the due increase of size in the animal, its old covering should be cast off and a new and enlarged one obtained. And this is what takes place throughout the *Annulosa*, the shedding of the shell of the Lobster and the moulting of the Caterpillar being but modified examples of the same principle.

These modifications may be reduced to three principal heads, of which the Spider, the Grasshopper, and the Butterfly may be cited as well-known examples.

In the first of these, the animal is produced from the egg in a form which it is destined to retain throughout its existence, its only change consisting in a series of moultings of the outer envelope, by which an increase of size, but not an addition of new organs, is acquired.

In the second, the animal at its exclusion exhibits the form which it retains through life, but it is subject to a series of moultings, during several of the last of which certain new organs are gradually developed.

In the third, the form of the animal at its exclusion from the egg is totally different from that in which it appears in its imago state, this change of form taking place during two or three of its final moultings, and consisting not only in the variation of the form of the body, but also in a complete change in the nutritive and digestive systems, and in the acquisition of various new organs. This constitutes what has generally been termed metamorphosis.

Now, since the *Ptilota* of Aristotle are preeminently the types of the invertebrated animals, and as such more distantly removed from the various groups of the *Vertebrata* than the remainder of the *Invertebrata*, (owing this preeminence not only to the superiority of their instincts, but also to the development of organs of flight during the latter moultings,) it will necessarily follow that those *Annulosa* which are less typical, or, in other words, more nearly allied to the lowest of the higher groups of animals, will not exhibit in so remarkable a degree those metamorphoses which, as we have seen, the *Ptilota* so peculiarly undergo.

Hence, since the organization of the *Crustacea* is more clearly analogous to that of the *Vertebrata* than that of the *Ptilota*, we arrive at one of the chief grounds for the

generally received opinion amongst naturalists, that the transformations of the *Crustacea* consist merely in the periodical shedding of the outer envelope, without any metamorphosis being undergone or additional organs acquired.

The object of the following pages is therefore to endeavour to ascertain whether this opinion be correct or not; and in order to do this satisfactorily we shall be obliged to test such observations which may negative its correctness, by the application of those general principles which, as we have seen, regulate the transformations or other changes of the *Annulosa*.

The non-existence of transformations in the *Crustacea* in general has been asserted by every crustaceologist, with the exception of a recent author, JOHN V. THOMPSON, Esq., F.L.S., (the accuracy of whose beautiful figures deserves the highest praise,) and by whom, in the first and succeeding numbers of the Zoological Researches, the discovery that the greater number of the *Crustacea* do actually undergo metamorphoses of a very peculiar kind, and of a totally different description from those of insects, has been announced. "So little has this been suspected by naturalists," observes this author*, "that the contrary has been assigned as one of the distinctive characters of the class, and been used as an argument for their separation from insects."

Mr. THOMPSON's views are founded upon some circumstances exhibited by some of the most singular animals hitherto ascertained to belong to the class, (which constitute the genus *Zoea* of Bosc,) as recorded by SLABBER or Mr. THOMPSON himself, as well as upon some other circumstances respecting other portions of the class. These consist,

In the first place, in a supposed change which the Zoes are reputed to undergo; respecting which Mr. THOMPSON (after alluding to the observations of SLABBER, which he thinks erroneous,) thus expresses himself: "After keeping a full-grown Zoe for more than a month, it died in the act of changing its skin and of passing into a new form, but one by no means similar to that expected [from the previous observations of SLABBER], as appears evidently by its disengaged members, which are changed in number as well as in form, and now correspond with those of the *Decapoda* (Crabs, &c.), viz. five pair, the anterior of them furnished with a large claw or pincer: the metamorphosis not having been completed, prevented any knowledge being acquired of its general form; enough, however, has been gained to show that the distinctive characters of *Zoea* and of SLABBER's changed *Zoea* were entirely lost; that the members, from being natatory and cleft (as shall shortly be shown), become simple and adapted to crawling only. On the 1st of May another large *Zoea* was taken, and dying towards the end of the month without having the strength to disengage itself from the exuvium, presented precisely the same results with the former†." In the account of the figures of this full-grown Zoe, "behind the corselet the rudiments of the limbs of the perfect animal, or Crab," are described as "beginning to show themselves‡;" but on comparing this figure with that of the newly hatched "Zoe,

* Zool. Illustr., p. 7. † Ibid., pp. 8, 9. ‡ Ibid., p. 33.

or larva of the common or edible Crab," (Pl. VIII. fig. 1.) "the disparity in size is shown between a Zoe newly hatched and one which has attained its full development, and the changes which the various parts undergo during the growth of the animal," (No. 2. Addendum,) as in the total absence of subabdominal fins, and in the natatory division of the two pairs of feet having only four plumose setæ in the younger animal: and in a former passage he observes, that "the larger specimens may be supposed to differ from such as occur of smaller size in the greater degree of development of all its parts; thus, the eyes are more distinctly pedunculate, the natatory division of the feet have an increased number of plumose setæ, the rudiments of the subabdominal fins are quite obvious, and the mandibles show the rudiment of a palp: in other respects they are essentially the same." (p. 10.)

In the second place, our author states that he had succeeded in hatching the ova of the common Crab (*Cancer Pagurus*), which presented exactly the appearance of *Zoea Taurus*, with the addition of lateral spines to the corselet. And in the addenda to his second number he has again stated this circumstance, adding somewhat more precisely, that he had protected a female Crab with spawn apparently ready to hatch until the young burst from their envelopes and swam about in myriads under the exact form of *Zoea* represented in the Plate.

In the third place, Mr. Thompson has stated that the common Lobster undergoes metamorphosis, "but less in degree" than any of the other genera in which he states that he had observed this to take place, and "consisting in a change from a cheliferous Schizopode to a Decapode, in its first stage being what I call a *modified* Zoe, with a frontal spine, a spatulate tail, and wanting subabdominal fins, in short, such an animal as would never be considered what it really is, were it not obtained by hatching the spawn of the Lobster*."

The only figure which accompanies this remark is given in tab. xv. fig. 13. of the same work, of "the cheliferous member of the larva of the Lobster, in which *a* is the claw; *b*, the outer division of the limb, or *future flagrum*; and *c*, the rudimentary branchia." In this figure, three organs are represented as arising from a large basal joint: first, the chelate organ, composed of two joints and a large didactyle chela; second, a three-jointed organ, of which the terminal joint is long, slender, and strongly setose; and third, a small rudimental branchia.

In the fourth place, "this curious piece of economy," according to Mr. Thompson, "explains what has ever appeared paradoxical to naturalists, viz. the annual peregrinations of the land Crabs to the sea-side, which, although acknowledged to be true by several competent observers, could never before be satisfactorily accounted for." (p. 9.) And again, in the Addenda to his second number: "Hitherto the rationale of this long and dangerous journey did not appear; naturalists have thought it strange that an animal entirely terrestrial should not spawn in its native haunts, and rear its young at home, instead of putting them to the trouble of a tedious and unknown

* Zoological Journal, No. xix. p. 383.

route back again in their very tender age. Scarcely a stronger confirmation than this very circumstance, of the universality of metamorphosis, could be adduced: for if there were any exception, it would be in the terrestrial species; but no, they are, when first hatched, incapable of living out of water with swimming members; hence the parent is impelled by instinct to seek that element for its progeny which Nature has designed for the whole of the tribe to which they belong. Having lived amongst West Indian islands, where these facts were constantly before him, neither he, nor any other person, could invent any plausible reason for this curious piece of economy."

In the fifth and last place are to be noticed Mr. THOMPSON's general statements. In the Addenda to his second number he states that he has had a confirmation of his views in one of the West Indian land Crabs, and in some other of our most widely separated native genera, authorizing his previous assertion that the greater number of the *Crustacea* do actually undergo transformations, of which, in addition to the facts adduced in his first memoir, further instances will be given in future memoirs. On the wrapper of his fourth number he has given a list of some of these promised memoirs, in which we find the *Paguri*, the Shrimp and Prawn, the genera *Porcellana*, *Gegarcinus*, *Hydrodomus*, and other genera of land Crabs and *Pinnotheres*, all stated to undergo various remarkable metamorphoses; and in the nineteenth number of the Zoological Journal he states that the newly hatched young of the following Brachyurous genera, *Cancer*, *Carcinus*, *Portunus*, *Eryphia*, *Gegarcinus*, *Thelphusa*?, *Pinnotheres*, and *Inachus*, have been ascertained to be Zoes by himself; and that the following Macrourous genera are likewise subject to metamorphosis, viz. *Pagurus*, *Porcellana*, *Galathea*, *Crangon*, *Palemon*, *Homarus*, *Astacus*.!

Such are the various circumstances upon which Mr. THOMPSON has built his theory of metamorphosis. I have given them at rather an inconvenient, but not an unnecessary length, and as far as possible in his own words, in order that I might be free from any charge of misrepresentation in the observations which I may think it necessary to make upon each of them, with a view to prove that the theory is without foundation.

For this purpose I propose, in the first place, to enter into a review of Mr. THOMPSON's observations, whence alone I conceive that no sufficient ground is raised for the establishment of the theory in question. In the second place, I propose to collect the recent views of the most celebrated crustaceologists, all of whom have advanced opinions to the like effect. And in the third place, I shall bring forward some circumstances observed by myself having a precisely similar tendency.

In the first place, therefore, I have to endeavour to prove from Mr. THOMPSON's own statements and figures, that there is not sufficient foundation for the theory of metamorphosis, and for this purpose I shall take in review *seriatim* the several circumstances which he has mentioned and above alluded to.

And first with respect to the metamorphosis into Crabs which the Zoes are stated to undergo, against which six arguments may be adduced.

1. It is to be observed that the account given of the mode in which this metamorphosis is supposed to be effected, is as vague and indefinite as it is possible to be. It is stated that the Zoe died in the act of casting its skin, but its metamorphosis not being completed, prevented any knowledge being acquired of its general form; and yet it is added that five pairs of legs had become disengaged, and that the characters of *Zoea* were entirely lost. Plate II. fig. 2., however, proves nothing like this. The limbs of the future Crab are asserted to be beginning to show themselves, and yet the Zoe retains its original form, without *losing* a single character which it previously possessed,—without our being able to trace the least appearance of the animal having commenced the shedding of the skin,—or without our being able to gain the least idea how "the members, from being natatory and cleft (*as shall shortly be shown*), become simple and adapted to crawling only." But Mr. Thompson has omitted to fulfill this promise, which, if it mean anything, must be understood as an assertion that the two pairs of natatory and cleft legs are transformed into five pairs of simple crawling legs.

2. The appearance of these limbs (represented as perfectly disengaged in Mr. Thompson's Plate II. fig. 11.) previous to the shedding of the cephalothoracic shield and anterior parts of the body, is totally at variance with the principles of ecdysis observable throughout the *Annulosa*, in which the locomotive organs, at least the legs, are the last which are disengaged, and the thoracic shield of the inclosed animal the first portion exposed to view. It would, in fact, be impossible for the Zoe to disengage the thoracic limbs without the thorax itself being previously withdrawn from its covering.

3. But we will look more precisely at the nature of this supposed disengagement of the five pairs of legs. This, in the absence of any precise explanation given by Mr. Thompson, may be presumed to be effected in three different ways.

Firstly,—as indeed Mr. Thompson appears to suppose by his statement that the large natatory limbs "become" simple ones,—this may be effected by the two pairs of large natatory limbs entirely throwing away their outer covering, whereby the five pairs of small simple legs, which had been previously inclosed within them, are disengaged. This I take to be the true nature of the disengagement of the organs of motion in the *Annulosa*; but if we regard this to take place in *Zoea*, we shall necessarily have two conditions totally at variance with the principles of ecdysis, viz. that an existing organ in a state of incomplete development incloses only a single organ,—thus, the wings of the Grasshopper are not inclosed within the legs of its larva; and that an organ disengaged by the shedding of its envelope is always larger than such envelope. This, in fact, is the very end of the metamorphoses of the annulose animals, the hardness of their outer covering preventing their growth, except by the shedding of such covering.

Secondly, We may imagine that the five pairs of minute rudimental legs of the future Crab are not transformed from the two pairs of natatory limbs, but are totally

unconnected with them, being, as Mr. Thompson himself says, "disengaged from beneath the clypeus", (and his Plate II. fig. 2. represents the same idea,) and having no previous existence in the young Zoe. Now if this be the case, setting aside its disagreement with the recognised conditions of development, we arrive at once at this startling and important conclusion, namely, that the large natatory organs of the Zoe are instrumenta cibaria, foot-jaws, in fact, and that the animal in its Zoe state has no true legs. Without, however, asserting (which might reasonably be done) that every annulose animal which in its immature state is furnished with locomotive organs, is also furnished with instrumenta cibaria, which latter legitimately represent the instrumenta cibaria of the imago, whilst the former as truly represent the *true* legs of the imago, we may assert, that where an immature annulose animal is furnished with locomotive organs, these, or at least some of them, represent the true thoracic legs of the imago, and are not, in such immature state, merely rudimental trophi of the perfect animal. Now on applying this principle to the case in question, we find the Zoe furnished both with trophi and natatory organs; and if we regard the trophi, although few in number, as representatives of the trophi, and the two pairs of natatory organs as representatives of the locomotive organs of the future Crab, we can only regard the five pairs of disengaged limbs either as representing the subabdominal appendages of the Crab, or as simple thoracic appendages (distinct from legs), or as supplemental limbs. But each of these suppositions is so contrary to nature with reference to the organization of Zoe or the Crab as distinct animals, that in order to show their futility it will be sufficient to notice the determinate leg-like form of these disengaged limbs, the first pair of which is cheliferous; the fact that the *Zoea* has distinct subabdominal appendages; that the *Crustacea* are not, like the *Myriapoda*, furnished with auxiliary limbs; and that true thoracic locomotive organs (which in Zoe, according to the principles above stated, must still remain undeveloped,) are constantly developed at the same time as, or even before, supplemental ones.

Thirdly, We may imagine the disengagement of these "future limbs" to take place in a mixed manner, by considering that the two pairs of natatory limbs of the Zoe produce the first, or chelate, and second pairs of legs, and that the three posterior pairs are simply disengaged from beneath the clypeus. Against this idea many of the preceding observations may be conjointly adduced; to which it may be added, that the similar size of these disengaged limbs is sufficient to prove that they must have undergone an equal degree of development. Moreover, in such case the chelate members, which are larger than the following limbs, must be produced from the first pair of natatory limbs of the Zoe, which are much smaller than the second pair.

I have in these observations left unnoticed the small member anterior to the claws, observed by Mr. Thompson, and considered by him as the rudiment of the outer foot-jaw, which offers still greater difficulties as to its nature if we adopt Mr. Thompson's views, but which, as I shall subsequently show, is a necessary organ of the Zoe.

4. In the next place it is to be observed, that Mr. Thompson's figures and statements relative to the gradual development of the Zoes are totally at variance with one of the received principles of ecdysis, which may be thus stated. When an animal undergoes a variety of moultings, attended by alteration in form or development of organs, there is a gradual tendency towards the organization of the perfect animal. Now Mr. Thompson expressly states that his large Zoes differed from the smaller ones in the greater degree of development of all their organs. This therefore is precisely what would occur in case the large Zoes were perfect animals; and it is precisely what would not take place if the subsequent state of the Zoe were a Crab.

5. It is worthy of notice that there are several peculiarities in *Zoea* so evidently partaking of the Macrourous type, that it is surprising that Mr. Thompson should not have noticed that these characters present themselves in so complete a state of development, when compared with the *Macroura*, as to negative the opinion that these animals would ever become Brachyurous. The elongated tail, the rostrated cephalothorax, but more especially the structure of the mandibles and two pairs of maxillæ, may especially be noticed.

6. If, as we shall subsequently perceive, there be no pretence for doubting the correctness of Rathke's researches upon the Cray-fish, which is clearly proved to undergo no metamorphosis, I think we are fully warranted from analogy in considering that the other Decapods do not undergo metamorphosis. Mr. Thompson, indeed, seems inclined to consider that in such case the Cray-fish "can only be regarded as one *solitary exception* to the generality of metamorphosis*;" although he had previously given his opinion of the weight of analogy in the second number of his Researches, by stating that "metamorphosis having been proved in a *single instance* amongst animals so uniform in structure as the *Homobranchia*, *we may safely infer from analogy*, as far as regards the particular tribe alluded to, that it is general."

These six considerations induce me to adopt the opinion that no sufficient ground has been shown by Mr. Thompson for supposing that a metamorphosis of Zoes into Crabs takes place.

Secondly, therefore, we will proceed to notice Mr. Thompson's statements relative to the hatching of the young Zoes from a female of the common Crab, and which he states took place under his own eye. It is much to be regretted that Mr. Thompson, having such ample opportunity, did not dissect the ova in various states, so as to ascertain in the most satisfactory manner the gradual development of the embryo, as Rathke has done in the Cray-fish. The statement, although short, has, however, such sufficient precision, that we are compelled to believe either that (notwithstanding whatever may be advanced to the contrary) the young of the common Crab are Zoes, or that the latter are parasitic animals, which in some unexplained manner are introduced in the embryo state beneath the abdomen of the Crab; and if we consider the large Zoes observed by Mr. Thompson to be perfect animals, there is some ground

* Zoological Journal, No. xix. p. 383.

for the latter opinion in their comparatively less perfect organization, a circumstance to which a completely analogous case exists amongst the *Hyperiidæ* in the order *Amphipoda*, &c. Zoe, indeed, is not the only animal respecting which this kind of parasitic obscurity exists; the genus *Meloe* amongst the coleopterous insects is perfectly analogous, the young of which, according to some authors, are *Acari*, whilst others state them to resemble the perfect insect. I am the more anxious to offer this explanation of Mr. Thompson's argument, in as much as the facts subsequently stated respecting the ova and young of the *Brachyura* are totally at variance with Mr. Thompson's assertions.

Thirdly, As respects Mr. Thompson's statements relative to the young of the common Lobster, we have again to regret the slightness of the information given to us upon this branch of the subject. The young is called a modified Zoe, a cheliferous Schizopode, with a frontal spine, a spatulate tail, and wanting subabdominal fins, undergoing a metamorphosis *less in degree* than the other mentioned genera. We are left in uncertainty whether there are eight pairs of locomotive organs, as in the true Schizopods, or whether these organs are all divided into two parts; the only evidence of such Schizopod nature being the chelate limb figured; and yet this is precisely where information was required. Examine the other characters given of this "modified Zoe" without reference to its undescribed legs, and we are able to trace (notwithstanding Mr. Thompson's assertion to the contrary) precisely such an animal as might be expected for an immature Lobster. But if we examine the nature of the cheliferous member figured, we shall find the strongest reason for considering that this "larva" is not a Schizopode. Fig. *a*. represents the cheliferous member of the perfect Lobster, as well as of its larva; but this organ is not provided in the perfect state with any lateral appendage. And Mr. Thompson himself does not attempt to prove the connexion of the lateral appendage which he figures with the cheliferous limb of the perfect Lobster, since he describes this lateral appendage as the *future flagrum* of the Lobster, that is, the lateral division of the exterior pair of foot-jaws; consequently, unless Mr. Thompson is prepared to prove that the lateral appendage of one organ in the immature state becomes the lateral appendage of a totally distinct organ in the perfect state of the same animal, it must follow that this gentleman has erred in his dissections of the immature Lobster, and mistaken the lateral appendage of the outer foot-jaw for a Schizopodous appendage of the Cheliferous limb.

Fourthly, As respects the explanation or "excuse" which this principle of metamorphosis enables us to give for the annual migrations of the land Crabs of the West Indies to the ocean to deposit their spawn, the young produced from which being natatory animals—Zoes, in fact,—are incapable of living in the same element as their parents in their early stages, I can very well agree with Mr. Thompson that if any exception existed amongst the *Crustacea*, in which the young should not undergo any change from aquatic to terrestrial habits, accompanied of course by a

corresponding modification of structure, it would be amongst the land Crabs; but I cannot agree with this gentleman that scarcely a stronger confirmation than this very circumstance could be adduced of the universality of metamorphosis, in as much as it appears to me that Mr. Thompson has arrived somewhat too suddenly at the conclusion that the young must consequently be Zoes, or even that, although incapable of living out of the water, they are necessarily furnished with natatory members. Examine the sea Crab, and no material difference in the structure of its locomotive organs is to be observed from that of the land Crab whence a different kind of motion can be inferred; hence there can be no actual necessity for the existence of natatory apparatus in the young land Crab, which must be just as able to support itself in the water without any such as an ordinary sea Crab. If, moreover, we examine the structure of the branchial apparatus of the land Crabs, we find still further evidence in support of this argument. MM. Audouin and M. H. Edwards, in the Annales des Sciences Naturelles for September 1828, have given an account of this organization: the exterior of the branchial cavity is furnished with a reservoir for containing a supply of water; and in the land Crab there is moreover a second vessel destined for the like purpose, whence it is evident that in this respect the land Crabs do not materially differ from the sea Crabs. I will not dwell upon this subject further than to refer to the conclusive facts subsequently stated in proof that the young of the land Crabs is neither a Zoe nor furnished with natatory apparatus.

Fifthly, I will only observe with reference to Mr. Thompson's general assertions, that no great weight ought to be attached to them until the necessary details shall have been given to the public, more especially if, as I have shown to be the case, we find cause in those already published to distrust the views of the author.

Having thus gone through the various statements made by Mr. Thompson in support of his theory, and ascertained from them the apparent want of confirmation of such theory, I proceed to notice the opinions of crustaceologists whose writings have established for them some degree of weight as authorities upon the question.

These observations will be confined, firstly, to such as bear directly upon Mr. Thompson's statements, and secondly, to such as relate to facts noticed respecting the transformations in the early stages of various animals in the class; since it is the more necessary in endeavouring to ascertain the correctness of the views of an author, to reject all general assertions made by others to the contrary which have not been made in reference to such opinion, or which do not rest upon direct observation. And it is to be regretted that Mr. Thompson's memoirs have been far from generally known; this will account for the slight degree of attention which has been bestowed upon the interesting subject upon which they treat, and for the paucity of notices respecting them.

We find Latreille*, however, stating that the opinion of Mr. Thompson "a grand besoin d'être étayée par des expériences positives, si toutefois elle n'est pas erronée."

* Cours d'Entomologie, p. 385.

M. Edwards, the most celebrated of modern living crustaceologists, observes, that as the *Malacostraca Podophthalma* are divisible from the presence or absence of branchiæ to the thorax, inclosed in a peculiar cavity, "on n'aura plus d'incertitude sur la place que doit occuper un genre très curieux, *Zoea*; en effet, un examen attentif de ces petits animaux m'a convaincu que non seulement leurs yeux sont portés sur des pédunclés, mais aussi de chaque côté de leur thorax il existe sous le carapace une cavité respiratoire renfermant des branchies semblables par leur structure et leur position à celles d'autres Macroures. Il est donc evident pour moi que le Zoe est réellement un Crustace de l'ordre des Décapodes. Mr. Thompson assure que cet animal n'est autre chose que le jeune de Crabe commun. Cette opinion me ne paraît pas soutenable, mais neanmoins il serait possible que les Zoes observés jusqu'ici ne soient pas des animaux adultes, et alors il se pourrait bien que par les progrès de l'âge ils deviennent assez semblables aux Megalops; question que nous nous proposons de traiter plus au long dans une autre occasion*."

The talented editor of the Zoological Journal has also, in his review of Mr. Thompson's work, expressed his doubts as to the universality of the fact of metamorphosis taking place in the *Crustacea*; and in the eighteenth number of that work he has stated the confirmation which his doubts had received by the publication of Dr. Rathke's work, adding, that if there existed no optical delusion or other cause of error in the isolated observations which Mr. Thompson has given us, the difference of organization between a Macrourous and a Brachyurous Decapod is much greater than either analogy or anatomy would have led him to suspect.

And lastly, Mr. Kirby has communicated to me his conviction that the researches of Mr. Thompson are to be regarded with distrust, the grounds for which opinion will appear in his forthcoming Bridgewater Treatise.

I now proceed to notice, as concisely as possible, the direct observations made by various authors upon different Crustaceous animals in the young state.

And in the foremost place are to be mentioned the elaborate researches of Rathke upon the development of the ova of the common Cray-fish, a work which for minute and delicate investigation is rivalled only by Lyonnet's celebrated memoir upon the larva of *Cossus*. Some idea may be entertained of the extent of these inquiries, from the fact that five large folio plates are completely filled with details of the structure, internal and external, of the ova in various states of development, and of the newly hatched animal. And so beautifully clear are the representations of these objects, and so completely is the development of the embryo to be traced through all its stages, that unless we believe the whole to be the work of a fanciful imagination, it is impossible to arrive at any other conclusion than that the Cray-fish does not undergo any change which can in the least degree merit the name of metamorphosis. A full abstract of this valuable memoir is inserted in the eighteenth number of the Zoological Journal, and in the Annales des Sciences Naturelles for August 1831,

* Ann. Sc. Nat., April 1830.

the latter of which is accompanied by four plates. I will therefore content myself with referring the student to these accessible sources, without attempting to give even an outline of the elaborate investigations in question.

Latreille, speaking of the young of the Cray-fish, says: "Les jeunes écrevisses, très molles au moment de leur naissance, et toute-à-fait semblables à leurs mères, se réfugient sous leur queue, et y restent pendant plusieurs jours et jusqu'à ce que les parties de leurs corps soient raffermies *."

Mr. Thompson himself, in the genus *Mysis*, has clearly shown that these animals, which he has proved to be most intimately allied to the Decapod *Macroura*, undergo a series of changes, which he states "cannot be considered as metamorphoses, but simply a gradual development of parts †."

The above appear to be all the direct observations hitherto made upon the *Podophthalma* (with the exception of those subsequently detailed from my own researches); but amongst the sessile-eyed *Malacostraca* we have more numerous observations.

Of these, as in the former, the researches of Rathke again stand foremost; since, in a series of memoirs, very recently published, upon the development of the ova and embryos of various animals, we find the common *Asellus aquaticus* to have been investigated by him, with the result that no material alteration takes place in the form of the animal ‡.

In the Annales des Sciences Naturelles for December 1833, is published a valuable report, by M. Isidore Geoffroy St. Hilaire, upon a memoir of M. H. Milne Edwards, entitled "Observations sur les changemens de forme que les Crustacés éprouvent dans le jeune âge." Passing over the more generalized views deduced by M. St. Hilaire from the facts noticed by M. Edwards, I shall merely state the latter. The genus *Cymothoa*, and some other Isopodous genera, afforded to M. Edwards an easy opportunity of examining the development of the eggs and the structure of the young, in consequence of their being inclosed within the large subthoracic pouch. Hence he was enabled to ascertain that some organs which are fully developed in the adult animal, are either rudimental or absolutely wanting in the early state: thus, in the latter the animal has only six thoracic segments, and six pairs of legs, although when adult it has seven segments and seven pairs of legs. On the contrary, other organs, which are fully developed in the young, become rudimental in the adult state: thus, in the former we find a large head, furnished with two large oval black eyes, and the abdominal segments nearly as large as the thoracic ones; whilst in the adult state the head is extremely small, the eyes are not externally visible, and the abdominal segments are very short and linear. M. Edwards has also made similar observations upon many other genera, especially upon *Anilocra*, in which a pair of legs is also developed after birth (the same likewise takes place in

* Règne Animal, tom. iv. p. 90. 2nd edit.

† Zoological Researches, p. 16.

‡ Abhandlungen zur Bildungs ant Entwickelung-geschichte des Menschen und der Thiere. 4to. 2 parts. 1832, 1833.

Oniscus, as De Geer long ago remarked); upon *Cyamus*, a genus of *Læmodipoda*, which in the young state is of a slender and cylindric form, but which afterwards becomes much enlarged and depressed; also upon *Phronyma*, a genus of *Amphipoda*, remarkable for its large head, conical thorax, and singular construction of the fifth pair of thoracic legs, but which in the young state exhibits a head of ordinary size, a thorax larger in the centre than at the extremities, and the fifth pair of legs not unlike the others, and not didactyle.

From the modification in form which the *existent* organs undergo in the passage to the adult state, M. Edwards deduces this curious theory,—that the changes of form which the *Malacostraca* undergo constantly tend to remove the animal to a greater distance from the type which is common to the greatest number of individuals in the group, so as to individualize it more and more completely. Thus the form of the immature *Cymothoa* or *Phronyma*, for instance, is referrible to the general typical form of the *Isopoda* or *Amphipoda*; but, by the gradual change of form, these animals are exhibited in forms the furthest removed from the types of their respective orders.

It is evident, however, from these remarks, that the *Edriophthalma* undergo no change worthy of the name of metamorphosis; and this is most fully supported by the observations of Latreille upon the *Isopoda* in general, viz. that the progeny "naissent avec la forme et les parties propres à leur espèce, et ne font que changes de peau en grandissant*"; of Mr. Montague upon *Caprella Phasma*, who states that he observed ten young ones crawl from the abdominal pouch of the female, "all perfectly formed"†; of Mr. Coldstream in an admirable paper upon *Limnoria terebrans*, inserted in the Edinburgh New Philosophical Journal of Professor Jameson for April 1834; and, lastly, of Professor Zencker in his memoir "De Gammari Pulicis Historia Naturali," 4to, 1832.

Hitherto I have confined these observations to the *Malacostraca*, because it is in that division of the class that the non-existence of metamorphoses has been denied. The *Entomostraca* are admitted on all hands to undergo very material modifications of form, as may be seen from the researches of Jurine, Strauss, Prevost, &c.; whilst Mr. Thompson's recent memoir upon *Artemia* (not *Artemis*,) is an additional evidence of the same fact, although the nature of the various alterations is very far from being detailed in that satisfactory manner which the author seems so capable of doing.

I have therefore now to detail, as the third portion of this essay, such circumstances as have fallen under my own observation relative to this interesting inquiry, the tendency of which is precisely similar to that exhibited by the two preceding portions of my treatise.

We have seen that Mr. Thompson's chief argument is founded upon the supposed transformations of the Zoe into a Crab. His Zoe, figured as the just-hatched larva of the common Crab, is not so large as a large pin's head. Slabber's "changed Zoe" is represented as three lines long; and Mr. Thompson's Zoe, which died on the sup-

* Règne Animal, tom. iv. p. 131. † Linnean Transactions, vol. vii. p. 66.

posed point of transformation into a Crab, is nearly four lines long between the tips of the spines. Now if Mr. Thompson's views be correct, and these latter Zoes are to be regarded as the larvæ of Crabs, they must be considered as having acquired the maximum of their Zoe form; but so far is this from being the case, that I have obtained from the collection of the late Rev. Lansdown Guilding, specimens of a species of *Zoea ten* lines long between the points of the spines; a size far too large to allow us to suppose that they would subsequently put off their Zoe form, and appear as Crabs; bearing at the same time in mind the minute size of the latter animals in the very young state, although possessing their ordinary form.

Of this West Indian species I have given, in the accompanying sketch, figures in detail of the various organs, which I shall not describe at length. The palpigerous mandibles, the two pairs of antennæ, one pair of which is bipartite, the multilobed inner maxillæ, are all characters found in the *Macroura* and *Schizopoda*, but not in the *Brachyura*. The natatory apparatus of the tail, observed in my species and unnoticed by Mr. Thompson, is also similarly characteristic, but the locomotive organs are those to which the highest importance attaches with respect to the real nature of the animal. At first sight, in addition to and immediately succeeding the two pairs of maxillæ, there appear only two pairs of large locomotive bipartite organs. These therefore, on the supposition that the Zoe is the young of a Decapod animal, must either be legs, or outer foot-jaws greatly developed; and from their bipartite structure, the latter may be partly assumed; but upon carefully dissecting the animal, a series of organs were found, which not only fully proved this to be the case, but also led at once to the discovery of the real nature of these animals, and gave a clue for the correction of Mr. Thompson's ideas upon the supposed disengagement of the thoracic limbs. Immediately succeeding the outer pair of the natatory organs, and, in fact, lying between them when at rest, was discovered a pair of slender minute organs, composed apparently of two joints, one long and one short, and furnished at the base with a still more minute lateral appendage. Beyond these, in succession, were found the five pairs of organs precisely similar to Mr. Thompson's "limbs of the future Crab disengaged from beneath the clypeus." Moreover, a number (undetermined) of minute fleshy elongated masses were found near and attached to the base of these limbs. Are we therefore, with Mr. Thompson, to suppose that in this Zoe (and all the specimens were alike) metamorphosis had commenced, whilst not the slightest trace of such a process could be observed beyond this acquisition of rudimental limbs, which can otherwise be much more satisfactorily accounted for? The researches of recent authors, and those particularly of M. H. Milne Edwards, have clearly proved that in some species of Decapods (*Acetes, Sergestes,*) one or more pairs of legs become rudimental, and that their place is supplied by highly developed foot-jaws.

Now upon applying this theory, to the correctness of which Mr. Thompson bears witness, to *Zoea*, we find that the two large pairs of natatory organs represent the

first and second pairs of foot-jaws of the typical Decapods immensely developed; the minute pair of organs following these to be the third pair of foot-jaws; the five pairs of "limbs of the future Crab" to be the real thoracic legs of the Zoe, and that the minute fleshy masses are evidently branchiæ. Thus we perceive that the possession of these limbs, instead of being an evidence of the imperfect state of the Zoe, is a proof of its anomalous perfection; and thus we arrive at the unexpected conclusion that *Zoea* is a genus of Decapod *Crustacea*, for the reception of which amongst the *Macroura* a distinct section must be established.

With reference to Mr. THOMPSON's statements respecting the hatching of the Zoes from the eggs of the common Crab, and the arguments adduced from the habits of the West Indian land Crabs, I am able to offer the following as, I trust, very conclusive observations to the contrary.

In the collection above alluded to were contained, in spirits, the abdomens of several female Crabs, having the interior surface covered with hundreds of eggs or newly hatched young. One of the bottles in which one of these was deposited was labelled by Mr. GUILDING, "Eggs and young of a land Crab not undergoing a metamorphosis." From this specimen I obtained eggs, and young Crabs evidently just hatched, and others at a rather later stage of their growth.

The eggs are of a dark reddish colour, showing through the outer integument the rudimental limbs of a future animal of a paler colour. On removing the thin transparent pellicle which surrounded one of these eggs, the eyes of the future animal were most conspicuous, the tail was seen extended as a narrow plate, nearly reaching to the eyes, and along its sides lay the large anterior cheliferous and the four following simple pairs of limbs. The existing organs, although perfectly discernible, occupied only a small portion of one side of the egg, its greater part being filled with hardened matter composed of minute molecular grains. The animal was in a sufficiently forward state of development not to allow the least doubt to be entertained as to the nature of these limbs, nor did any organs appear answering to the two large split pairs of natatory organs of *Zoea*. The branchiæ, in a fleshy and unorganized state, were also found at the base of the legs. The eggs are $1\frac{1}{3}$ line in diameter.

In the accompanying sketches I have represented one of the Crabs evidently just hatched, being about $1\frac{1}{4}$ line long, and having the upper part of the cephalothorax considerably swollen. From my figures, the very rudimental state of the two pairs of antennæ, and of the feelers or flagrums of the outer foot-jaws, will be perceived; but the general form of the animal is thus early exhibited, and the developed state of its branchiæ and the want of subabdominal appendages are especially noticeable. In the following sketch the animal is seen in a somewhat more advanced stage of its growth, being rather more than 2 lines long, and in which the upper surface of the cephalothorax has acquired its ordinary shape, and the antennæ have attained a greater degree of perfection.

These circumstances are, I trust, amply sufficient to prove that the land Crab does not undergo any metamorphosis.

It is to be observed that Mr. GUILDING has not stated the precise species of land Crab of which the above-mentioned individuals were the offspring; but his well-known acquirements in crustaceology put the question of its being at all events a species of land Crab to rest. Should this, however, be nevertheless called in question, the argument which I would deduce from it will be but little diminished even were it a sea Crab.

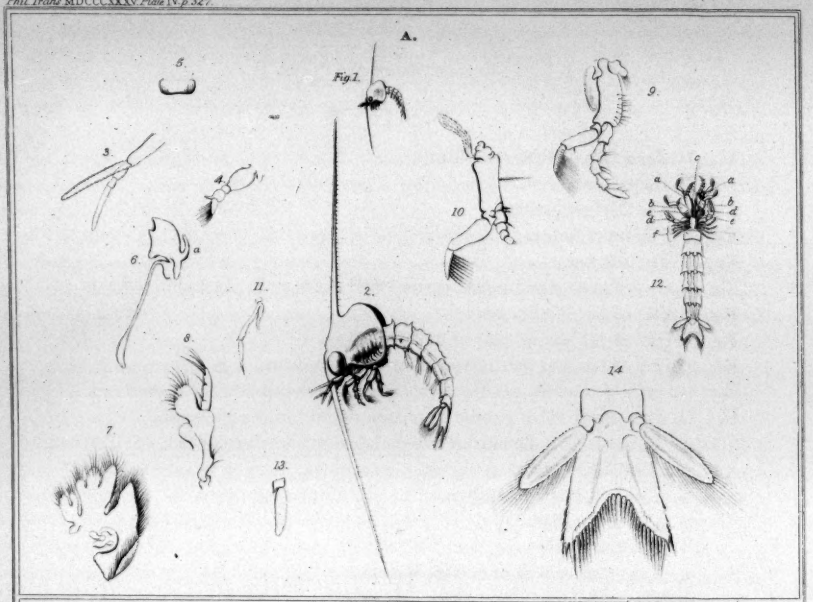
We have seen that Mr. THOMPSON's supposed full-grown Zoe, which died on the point of undergoing its supposed metamorphosis, was 3 lines long between the points of the spines, and the length of which, from the head to the tail, must have been at least $1\frac{1}{2}$ line. But the young of the common Crab is found of a much smaller size than this, exhibiting at the same time all the form of the full-grown Crab. I have myself captured the young of *Cancer Mœnas* not more than $\frac{1}{2}$ a line long, yet perfectly formed, and capable of running about with much quickness.

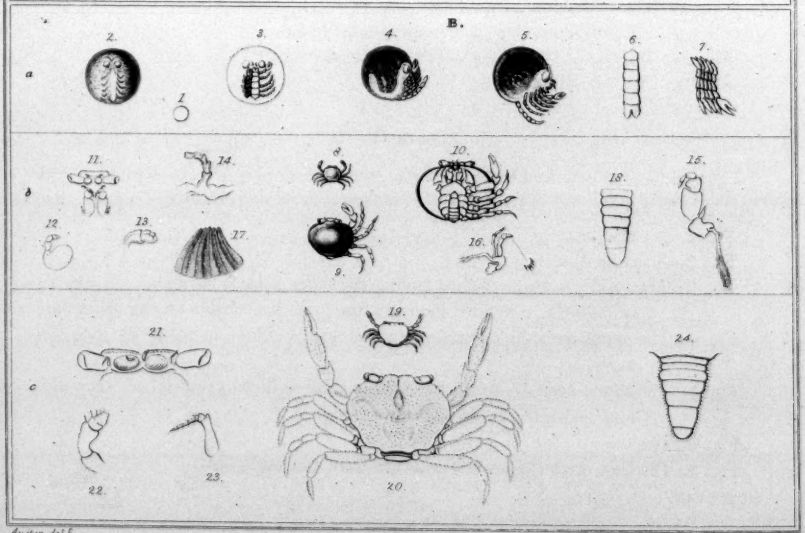
Although disagreeing with Mr. THOMPSON in respect to his theory, I have already stated that his figures are very faithful delineations of nature. I have therefore the more pleasure in stating that his representations of the young of *Mysis* are (as I have ascertained by extracting them from the subthoracic pouch of the female) correct.

Hence, by taking the preceding observations into consideration, we find that one or more types of each of the great groups of the typical Malacostracous *Crustacea* have been ascertained to undergo no change of form sufficiently marked to warrant the employment of the term metamorphosis. Thus,

The *Brachyura* are represented by the Land Crab.		
The *Macroura*	———	Cray-fish.
The *Schizopoda*	———	*Mysis*.
The *Amphipoda*	———	*Gammarus* and *Phronyma*.
The *Lœmodipoda*	———	*Caprella* and *Cyamus*.
The *Isopoda*	———	*Asellus*, *Cymothoa*, and *Limnoria*.

Note.—Since the preceding pages were written, Mr. THOMPSON has published a memoir upon the genus *Pinnotheres*, belonging to the *Brachyura*, in which the ova are stated to have been seen to hatch in great numbers under the form of a new kind of Zoe, without the circumstances attending their development being recorded. And, on the other hand, some of the late Mr. GUILDING's MSS. have been published in the Magazine of Natural History, in which it is distinctly stated that the land Crabs do not undergo transformations.





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Explanation of the PLATE.

PLATE IV. A.

Fig. 1. *Zoea Gigas*, WESTW. natural size.
Fig. 2. Ditto, magnified.
Fig. 3. The outer antenna.
Fig. 4. The inner antenna.
Fig. 5. The labrum.
Fig. 6. One of the mandibles, a representative of the the palpus.
Fig. 7. One of the interior maxillæ.
Fig. 8. One of the second pair of maxillæ.
Fig. 9. One of the first pair of foot-jaws, developed into a natatory organ.
Fig. 10. One of the second pair of foot-jaws, developed into a natatory organ.
Fig. 11. One of the third pair of foot-jaws, minute and rudimental.
Fig. 12. View of the underside of the body, as extracted from the cephalothoracic shield.
a. The first pair of foot-jaws.
b. The second pair.
c. The third pair.
d. The anterior pair of chelate members.
e. The rudimental branchiæ.
f. The four posterior pairs of simple members.
Fig. 13. One of the subabdominal appendages.
Fig. 14. The tail, developed.

PLATE IV. B.

"Eggs and young of a land Crab not undergoing a metamorphosis."—GUILDING, MSS.

a. The egg.
Fig. 1. Natural size.
Fig. 2. Magnified, seen in front.
Fig. 3. The same, seen in front, having the outer pellicle stripped off: the legs on one side extended laterally, the branchiæ visible on the other side.
Fig. 4. The same, seen in front, having the outer pellicle stripped off, seen sideways.
Fig. 5. The same, seen in front, having the outer pellicle stripped off, seen sideways, with the limbs and tail extended.
Fig. 6. The tail.
Fig. 7. The legs, with the branchiæ at the base, not organized.

b. The young in its earliest state.

Fig. 8. Natural size.

Fig. 9. Magnified.

Fig. 10. Ditto, seen from beneath.

Fig. 11. Anterior portion of the body, from beneath, showing the outer foot-jaws, two pairs of antennæ, and eyes at the extremity of the peduncles.

Fig. 12 & 13. One of the rudimental internal antennæ attached to a large fleshy tubercle.

Fig. 14. One of the rudimental external antennæ.

Fig. 15. One of the outer foot-jaws.

Fig. 16. One of the intermediate foot-jaws.

Fig. 17. The branchiæ.

Fig. 18. The abdomen, unfurnished with internal appendages.

c. The young at a rather more advanced period.

Fig. 19. Natural size.

Fig. 20. Magnified.

Fig. 21. The anterior part of the body seen from beneath.

Fig. 22. One of the internal antennæ separated from its large basal lobe.

Fig. 23. One of the external antennæ.

Fig. 24. The abdomen.

XVIII. *On the Ice formed, under peculiar circumstances, at the bottom of running Water.* *By the Rev.* JAMES FARQUHARSON, *of Alford, F.R.S.*

Received March 17,—Read April 2, 1835.

ICE formed at the bottom of rivers and streams, frequently in great quantities, is a phenomenon quite common in this climate. I made for several years past a number of incidental and desultory observations upon it, and became convinced that the principal explanation of its occurrence is the radiation of heat from the solid opake materials of the bottom; but as I conceived this to be also the generally admitted one, I took no note of the observations, with the view of vindicating the theory of the radiation. It appears, however, from a paper of M. ARAGO upon the subject, translated and published in the Edinburgh New Philosophical Journal, vol. xv. p. 123, from the Annuaire for the year 1833, that he entirely rejects the theory of the radiation of heat through a thick layer of water. In the same paper, although he does not, in conclusion, pretend to give a complete explanation of the phenomenon, he brings forward, as explanations in part, three circumstances, which, although accurately stated by him, appear to be not exclusively appropriate to ice formed at the bottom, and cannot therefore aid us in solving the main question which we have to discuss here, which I apprehend to be, *Why is ice formed sometimes on the surface of running water, and sometimes at the bottom?*

On reading M. ARAGO's paper, I became desirous of offering some remarks in answer to it, as without some one doing this, on proper data, a misapprehension concerning the cause of a natural phenomenon, so much at variance with our most frequent experience of the formation of ice only on the surface of all waters, as to have often greatly excited the attention and even called forth the astonishment of scientific men, would continue to be propagated under the authority of a distinguished name. Having, however, no record of my former observations to enable me to refer accurately to the time, place, and other circumstances of them, I delayed till a renewed occurrence of ice on the bottoms of our streams should enable me to repeat them.

Such an occurrence, on a great scale, took place in the beginning of this month of January (1835); and I now have the honour of presenting to the notice of the Royal Society a brief account of the observations I have been enabled to make, and of the conclusions to which they appear to direct us.

Previously to entering on this detail and discussion, it seems proper to describe the appearance and quality of the ice formed at the bottoms of streams. A misapprehension regarding these may have been one cause of the incredulity of its existence,

entertained by some persons who have never witnessed it, and which M. Arago, in the paper referred to, has deemed it necessary to remove, by bringing forward the testimony of many distinguished men to its reality. The ice formed at the bottom does not resemble the solid glass-like plates which are formed on the surface. It has nearly the aspect of the aggregated masses of snow as they are seen floating in rivers during a heavy snow shower; but, on taking it out of the water, it is found to be of a much firmer consistence than these, although never approaching to the firmness and solidity of surface ice. It is a cavernous mass of various-sized, but all small, pieces or crystals of ice, adhering together in an apparently irregular manner by their sides, or angles, or points, promiscuously. Both the firmness of the adhesion and the dimensions of the interstices (the latter filled with water, and their volume easily estimated by the quantity of it which is discharged when the ice is lifted out of the stream,) are, however, greatly modified by the intensity and continuance of the previous cold. When the ice begins first to form on the bottoms of the streams, it presents a rudely symmetrical appearance, which, for illustration, may be compared to little hearts of cauliflowers, fixed on the bottom, having a similar uniform circular outline and protuberance in the centre, with coral-like projections. These pieces have a shining silvery aspect; they are dispersed, at first irregularly, in small numbers, but increase both in size and numbers, till the whole bottom is covered, and, if the frost continues severe, grow in height, but in a very irregular manner, so as to obliterate the earlier somewhat symmetrical shapes, till the streams are raised high above their former levels, and frequently made to overflow their banks. And here I take the opportunity to notice the incorrectness of an observation of Desmarest, quoted by M. Arago, and which, M. Arago observes, no one has corroborated, "that it was from the lower parts, which touched the bottom, that the flakes of ice successively increased." On the contrary, the forms of the surface of the earlier masses are continually obscured, in succession, by new ice added to the top.

This congealed mass being thus very different in appearance and consistence from the sheets or plates generally known by the name of ice, it were no doubt well that, like the Germans, who, M. Arago informs us, name it *grundeis*, we too designated it by another name, to prevent confusion or misapprehension when we refer to it. The inhabitants of this part of the country will furnish us with a better one than even that of the Germans. In a district where it occurs almost every winter, and often repeatedly during that season, and where many of the rivers are crossed by means of fords, its existence influences too much their economical arrangements not to excite their particular attention, especially as many horses refuse to enter any stream even slightly impeded by it, being greatly alarmed by the pieces which break and float up from the bottom by the action of their feet. A body with which all are so well acquainted is known by an appropriate name. They call it *ground-gru*; *gru* being the term by which they designate snow saturated with, or swimming in water. I shall venture to use their term for the ice formed at the bottom.

It will be better here also to state, generally, the conditions of temperature and phases of the weather under which the ground-gru is formed. I have seen it occur only when the temperature of the whole mass of water was reduced to, or nearly to, 32° FAHR., and when the temperature of the air was several degrees below that point. I have observed it an invariable condition, that it was preceded by a continuance, for some time, of a clear, or very nearly clear, state of the sky. This is at variance with another observation of DESMAREST, quoted by M. ARAGO, that "when, in consequence of a cloudy sky, the atmospherical temperature experiences little variation throughout the day and night, the ice at the bottom of the water uniformly increases every twenty-four hours; on the contrary, when the sun shows itself, the ice does not increase during the day." It is the fact, that while it is forming under the continuance of a cloudless sky, its increase is impeded during the day. It may be possible, amidst the infinite variety of measures of cold that may exist at the time, that the increase of the gru may go on for a little time after the sun has been obscured by a thin cloud; but I have always seen, that when a densely clouded state of the sky supervened, and continued for the space of even only twenty-four hours, the gru became detached from the bottom, and floated down the stream. Should the temperature of the air continue low, with the clouded sky, or get lower, the ground-gru is not renewed, but the river is speedily frozen over at the surface. It is, in fact, a matter of frequent occurrence, in frosty winters, that our rivers, filled, and so impeded, by ground-gru, as to be raised above their banks, are found returned into their natural channels, and there frozen over at the surface, but flowing over a clear bottom, in a space of time so short as to appear very wonderful to those who have not investigated the cause. The process is named, by the country people, the *flitting* of the ice. In opposition to the observation of DESMAREST, and in confirmation of those which I have made, on this point, I may refer to the Rev. Mr. EISDALE, who, not satisfied with the explanations of M. ARAGO, has published one of his own, in the Edinburgh New Philosophical Journal, vol. xvii. p. 167. His explanation appears equally unsatisfactory, as will be shown afterwards; but the part of his statement we have to do with here is his notice of this observation of DESMAREST. The formation of the ground-gru, under a cloudy sky, is so much at variance with the information which Mr. EISDALE had received, that he resolves DESMAREST's "cloudy sky" into "an atmosphere loaded with hoar frost, and rendered hazy by its condensation *." The state of the air, in respect of being windy or calm, deserves also to be noticed. The ground-gru occurs most frequently during calm, with a deposition of hoar frost upon the ground at the time; and this was the condition of matters during the observations now to be detailed. But it also occurs during a frosty wind, when there is no hoar frost, which is formed only in a calm state of the atmosphere. The formation of the gru during wind, and consequently without any deposition of hoar frost on the ground, is especially to be noticed in reference to Mr. EISDALE's explanation,

* p. 172.

as will be afterwards seen. It occurred to M. Hugi, as quoted by M. Arago, in the Aar, on the 16th February 1827, with a west wind, after the river had been completely open on the 15th; and one of Mr. Eisdale's correspondents ascribed its occurrence in one particular instance, which he related to him, to the prevalence of a very sharp north-east wind, which had blown during the night of its formation.

The following observations were made in the rivers Don and Leochal. The former, having an easterly course, is about 120 feet broad, and a foot or two deep at the shallows and fords. The latter, one of the small tributaries of the former, having a northerly course, is about 20 feet broad, and a foot deep at the shallows. Both rivers possess a like character of very clear water, and alternating rapids and pools. The rapids in the Don are reaches, where the water falls two or three, or more, feet, from a higher to a lower level, within a distance of fifty or a hundred, or sometimes two or three hundred, yards. They are generally impeded with many large stones, some of them projecting above the water. The depth varies greatly, but seldom exceeds two or three feet. The pools between the rapids are on an average much longer reaches, in which there is little fall, and a greatly diminished velocity of the stream, which often, in them, flows so equably as to give rise to no ripple on the surface. They too have in them large stones, but fewer in number. The depth in them too varies greatly, from two or three to four or five feet. The rapids and pools in the Leochal are of a similar kind, but both much less deep in this smaller stream. The bed of this river has however, on the whole, a steeper descent, and owing to this there is more broken water and spray in the rapids. The character of alternating rapids and pools, in both streams, is owing to the varying hardness of the granitic and micaceous-schistose rocks in which their beds are formed. Where the rocks are hard, there is a rapid; where more friable, a pool. In the parts of the rivers observed, the original rocks themselves do not anywhere form the immediate bed of the stream. That, to the depth of two or three, or more, feet, is composed of the debris of these rocks, broken up and sometimes much waterworn, and reduced to the size of a very large gravel, by the action of the stream, but not so small as to deserve to be named sand. No part of the bottom is muddy.

On the night between the 31st of December 1834 and the 1st of January 1835, after the mean temperature of the air had continued for three days at 47° Fahr., and when there had been little frost in the season before, there commenced a hard frost, with a calm and perfectly cloudless sky, which continued with little abatement till the 5th of January, at 10 A.M. On the night between the 3rd and 4th, the temperature of the air was 23° Fahr.; and on the 4th, the bottoms of the rapids in the Leochal were seen coated in some places with silvery cauliflower-shaped clusters of ground-gru. I neglected at this time to examine the temperature of the water.

Between the 4th and 5th, the temperature of the air was down to 19° Fahr.; and on the 5th I examined the Don and the Leochal along half a mile of each, beginning the examination at half-past 8 o'clock A.M. The examination began at the bridge of

Alford, built of granite over the Don, in the middle of one of the rapids. At this rapid, the whole bottom, with the exceptions to be immediately stated, was covered with silvery gru, appearing from two or three to five or six inches deep. My attention was particularly directed to the exceptions, as throwing a clear light on the question of the radiation of heat from the bottom. Round each of the piers, and in front of the abutments of the bridge, there was a space quite clear of all frozen matter, excepting at a side of one pier under an arch, where a piece of very still water, caused by an obstruction at the bottom, was covered by clear sheet ice. On the south side of the river, two embanking walls, one up and the other down the stream, each twelve yards long, are built in a line with the water-courses of the abutment. Close to the bridge these walls are eight feet high from the bottom of the stream, but as they recede from the bridge the masonry slopes gradually to a lower level, till the extremities are little above the level of the water. The bottom in front of these walls was clear of ground-gru, as well as that in front of the abutments; but the breadth of the clear space in front of the walls narrowed gradually towards their extremities, in proportion as the masonry became lower, till at the extremity of the downward wall especially, which ends at a sloping gravelly bank, the gru came to the edge of the water. The space of the bottom clear of gru was about five or six feet broad at the high parts of the walls next the bridge; and the water runs on the place at the medium depth and velocity of the rapid. There was another clear space in the bottom of this rapid. About twenty-five yards above the bridge there is, in the middle of the stream, a piece of still water, caused by an elevated bed of gravel, just below it, over which the stream is very shallow. The still water, for an extent of two or three square poles, was covered with sheet ice, and that again covered by a very thin, but white, opake deposition of hoar frost. From under this ice the water, flowing rapidly over the gravel bed below, had no ground-gru for a space of eight or ten yards downwards.

Above this rapid, a pool of moderate stillness, about three or four feet deep, extends a hundred and fifty yards in length. Over the bottom of this there were scattered, in an irregular manner, many cauliflower-shaped clusters of silvery gru, most of them very small, and none that were observed covering more of the bottom than a square foot or two at one place. In the deepest and stillest part of the pool there were several tufts of water starwort, with sooty-coloured decaying leaves, forming the darkest-coloured objects seen at the bottom. These were all densely tangled with fringes of silvery gru. At the head of the pool, where the velocity acquired by the water in the rapid immediately above it was not yet greatly diminished, an appearance of a different kind presented itself. There are here several large stones in the bed of the stream, but none of them projecting above the water. On the faces of these opposed to the stream there were seen quantities of gru of a different aspect from that further down. It was not arranged in the same cauliflower shapes, but in angular masses, like wreaths of snow blown by the wind. It wanted, too, the silvery glance of the other, and had more the appearance of a pale ash-coloured mud. On

reaching it with the end of a pole, its consistency was found to be less firm; in fact, it was only a heap of detached uncemented spiculæ pressed against the stones, and retained there mechanically by the action of the water, in a certain modified state of its velocity. The source of these heaps of uncemented spiculæ will soon be noticed. This pool, as indeed was the case with all the pools in the river, had at its edges and in its little bays narrow pieces of surface-ice, extending a foot or two from the banks.

The rapid immediately above this, not unlike that at the bridge, was covered at the bottom with silvery gru, with one exception. The river was low at the time from long-continued deficiency of rain, and the water had deserted the south side of the channel, leaving many little pools among the stones, communicating more or less freely by irregular little currents with the main stream. The pools were covered over with sheet-ice, and that with a thin opake deposit of hoar frost like snow. In the little currents returning from under this ice there was no frozen matter.

At the head of this rapid there is a pool much deeper and stiller than that above the bridge-rapid already described. The depth is five feet, and the stillness such that, at many points of it, there is no ripple or wave on the surface. None of the silvery cauliflower-like ice was seen on the bottom here; but near the head of it, in a modified state of the current pouring in from the rapid above it, there were, on the faces of several large stones opposed to the stream, collections of uncemented icy spiculæ.

The source of these collections was very readily observed in a great rapid immediately above this. In that rapid the water has a much quicker descent than in the others referred to. It is about a hundred yards long, and cumbered with many large stones, over which, at many points, through its whole length, the water breaks with a great deal of spray. Here an immense quantity of gru occupied the bottom, impeding much the course of the stream. At the time of observation many pieces of this gru were seen edging up, and in some instances breaking quite away from the bottom, apparently by the increasing pressure of the water, as it became dammed back by the increase of the gru itself. This at least was the appearance, although there may have been another cause for the disengagement of it from the bottom, and that is, the impeding, by the imperfectly translucent gru, of that radiation of heat from the bottom which, I trust in conclusion to demonstrate, is the immediate chief agent in the whole phenomenon.

It is now to be observed, that a number of pieces of loose gru, the origin of which was so clearly ascertained at this last rapid, were floating down in all parts of the river. In passing through the rapids, they were broken into fragments, and, where the fall was violent, shivered into minute pieces. The larger pieces that remained after passing through the rapids floated at the surface, immediately as they got into the uniformly flowing currents at the heads of the pools; but the minuter ones, mixed with the water to all depths by the plunging whirls in the rapids, not being so speedily disentangled from their cohesion with the water, by the action of gravity, floated

for a greater distance immersed in the water, and were intercepted by, and mechanically retained against, the faces of the stones by the action of the stream at the heads of the pools. Further down, and in stiller water, where no such intercepted heaps were seen, their buoyancy had, no doubt, by degrees, overcome the cohesion and raised them to the surface; and in fact, in the still water, many minute icy fragments were floating in the surface.

Mr. KNIGHT, the celebrated botanist, quoted by M. ARAGO, has obviously, in part, but not completely, distinguished between the "frozen matter which reflected a silvery kind of whiteness," which covered the stones in the rocky bed of the river, and "floating spiculæ under water," which he found to "accumulate much more abundantly upon such parts of the stones as stood opposed to the current, where that was not very rapid, below the little falls or very rapid parts of the river."

In the smaller stream of the Leochal, the quantity of ground-gru was comparatively much more abundant, occupying the bottoms both of the pools and rapids in close masses, and in the latter, at many parts, forming such an impediment as to urge the water over its usual banks. But there were two remarkable exceptions. One of the pools flows close to the foot of a steep bank about fifteen feet high, and in the side next the bank there was little ground-gru. In a rapid, which at a turn of the river has an easterly course, there was a very dense fringe of *Phalaris arundinacea* standing, with its dense foliage of withered leaves, in the south edge of the water. Its height was four feet, and it extended fourteen feet in length along the stream. At the foot of it the bottom of the rapid was clear of ground-gru to the breadth of three feet.

The temperature of the air and water, at the time of these observations, was particularly ascertained. That of the air at sunrise, about an hour before the observations commenced, had been 23° FAHR.; but it was rising rapidly during their progress, and was at 36° FAHR. before their conclusion. The temperature of the water in the Don varied from 32° to 33° FAHR.; but the variation could not be distinctly traced as depending on the depth or velocity, as there was a temporary variation in the same place, both in the pools and rapids. At one of the small streams, returning from under the sheet-ice on the little pools at the edge of one of the rapids, the temperature was nearly steady at 33° FAHR. In the Leochal the temperature was nearly steady everywhere at 32° FAHR.

By 10 o'clock A.M. on the same day, a cloud obscured the whole sky, and at 2 o'clock P.M. the temperature of the air was 40° FAHR. At this time much gru rose from the bottom and floated down the streams of both rivers. The relaxation of the frost, however, was of very brief continuance. Before sunset the temperature of the air was again down to 31° FAHR., with a perfectly calm air and clear sky; and the clear sky continued till the evening of the 7th of January, the thermometer during the two intermediate nights being at 23°, and during the intermediate day at 26°.

The same parts of the Don and Leochal were again examined at 10 o'clock A.M. on

the 7th. In the Don the ground-gru now covered all the bottoms of the pools as well as of the rapids. It was of less depth in the deep still pool below the great rapid; but everywhere else it formed a great impediment to the stream, raising it so much above its former level that it covered deeply the pieces of sheet-ice formed at the edge on the 5th. New pieces of similar ice were now forming at the same places on the more elevated surface. The Leochal was still more impeded by the gru than the Don.

But, what is worthy of particular notice, the clear spaces of the bottom, at the piers, abutments, and embanking-walls of the bridge on the Don, and at the Phalaris grass in the Leochal, still continued so, but were now considerably narrowed in their lateral dimensions, the ground-gru having encroached upon them on the sides next the streams. The temperature of the air was 24° Fahr.; of the water, everywhere nearly steady at 32°.

Several circumstances occurred on some subsequent days which deserve to be noticed, as throwing light, by the contrast which they exhibit, on the phenomenon now under consideration. On the 8th of January there occurred a thaw, when the thermometer suddenly rose to 47° Fahr. The rivers were speedily cleared of ice and ground-gru, which last rose from the bottom and floated away with the stream. The atmosphere at the time was considerably clouded, with a brisk S.W. wind. On the 9th of January the temperature of the air fell to 36° Fahr.; and on the morning of 10th of January, with a temperature of the air at 29° Fahr., there was a fall of snow, of about an inch deep, which ceased by 8 o'clock A.M. The snow that fell into the rivers was observed to be entangled, and stuck fast, in irregular crushed masses, in many parts of the rapids; and there were collections formed of loose spiculæ of a muddy aspect, at the sides of the stones opposed to the streams, in the heads of the pools, where the velocity of the currents was intermediate between that of the rapids and that of the stiller parts of the pools; but there was no appearance on any part of the bottom resembling the symmetrical cauliflower-shaped ground-gru. On the evening of the 10th the temperature of the air fell to 23°, and continued at from 23° to 21° till the morning of the 12th, with a densely clouded state of the sky. During this time extensive sheets of surface-ice were formed on the pools of the Don, and many of the pools of the Leochal were quite frozen over, but the ground-gru was nowhere renewed; on the contrary, the masses of snow entangled in the rapids on the 10th disappeared to a great extent, obviously floating away in the stream. In this state of the river and weather, the collections of uncemented spiculæ, on the faces of the stones opposed to the streams in the heads of the pools, appeared in their places the same as before, neither increasing nor diminishing in size.

M. Arago, in his paper, refers to three circumstances, as partly, at least, explanatory of the formation of ground-gru in running water.

1st. The inversion, by the motion of the current, of the hydrostatic order, by which the water at the surface, cooled by the colder air, and which at all points of the tem-

perature of water under 39° Fahr. would, in still water, continue to float on the surface, is mixed with the warmer water below, and thus the whole body of water to the bottom is cooled alike by a mechanical action of the stream:

2nd. The aptitude to the formation of crystals of ice on the stones and asperities of the bottom, in the water wholly cooled to 32°, similar to the readiness with which crystals form on pointed and rough bodies in a saturated saline solution:

3rd. The existence of a less impediment to the formation of crystals in the slower motion of the water at the bottom, than in the more rapid one near, or at the surface.

There is no denying the justness of these three positions, and yet the slightest reflection teaches us that neither singly nor combined do they aid us in answering the main question before us, "Why is ice formed sometimes at the surface of running water, and sometimes at the bottom?" All the circumstances, or conditions, referred to by M. Arago, are present when ice, as most frequently takes place, is in the course of being formed only on the surface, as well as when the formation is going on at the bottom. Were we to admit them as an answer to our question, then running water ought always to freeze first at the bottom. But a most extensive experience teaches us that this is not the case. The illustrations of M. Arago, indeed, just and true in themselves, are not to be overlooked when we would investigate and explain the formation of ice either at the bottom or at the surface. They will serve to enlighten us greatly in both these events, but they have no exclusive relevancy to either, and we must therefore look out for another solution of the problem.

M. Arago, in his conclusion, does not present these three circumstances as a complete explanation; but he says, the reader may ask why he has not done so, and he answers to this, "that we have no observations which prove that this kind of ice is seen, until the temperature of the whole of the water is at zero" (centigr.); and that it is not certain that the little icy particles, seen by Mr. Knight, floating on a milldam, at the time ground-ice was forming in the stream, and which may have acquired in contact with the air a temperature below zero (centigr.), do not play an important part in the phenomenon which he has overlooked.

In regard to the former of these points, I cannot say what M. Arago would have deduced from it, had it been established in one way or the other. The observations made on the Don on the 5th of January show that the temperature of the whole water was not quite down to 32° Fahr. when the ground-gru was forming in large quantity. In regard to the latter, the little icy particles seen by Mr. Knight, the same condition belongs to them that belongs to the circumstances professedly adduced by M. Arago as explanations; that is, they occur as well when the ice is forming on the surface only as when it is forming on the bottom. They account well, however, for the collections of frozen matter seen by him at the sides of the stones opposed to the stream, in parts where its velocity had a certain modification.

And here I may advert to the explanation offered by the Rev. Mr. Eisdale, in his paper already referred to. From the information he received, he was led to believe

the ground-gru does not occur but when there is a hoar frost on the ground; and he explains the ground-gru to be particles, or crystals as he afterwards names them, of hoar frost precipitated into the water, retaining there the shapes in which they descended, brought into contact with the rocks by the agitation of the water, and forming nuclei for the accumulation of ground-gru. Could it be proved that such crystals are precipitated into the water, they would serve no more for explanation than the icy particles of Mr. KNIGHT. We have learnt, indeed, from travellers in high northern regions, that, in certain states of cold and moisture of the air, such crystals, as Mr. EISDALE assumes, are there seen and felt floating in it; but nothing of that kind was observed in January last; and when Mr. EISDALE, from the existence of spiculæ of hoar frost on the ground, would infer the like may be formed in the air to fall into the water, he neglects to take into the account, that the spiculæ of hoar frost have not fallen from above, but that their symmetrical arrangement, round on all sides of the bodies on which they are found, and their slow increase, prove they have been deposited on their places by a gradual deposition of invisible watery vapour, owing to the substances to which they are attached being cooled below the temperature of the surrounding air, by the radiation made known to us by the experiments of Dr. WELLS. Besides this we have to remark, that the ground-gru sometimes takes place, agreeably to the information of one of Mr. EISDALE's own correspondents, in a windy state of the atmosphere, at which time no hoar frost is seen.

The interesting experiments of Dr. WELLS just referred to enable us to give, after all, a very satisfactory explanation of the ground-gru; and Mr. M'KEEVER, quoted by M. ARAGO, had gone far to illustrate it by means of them, although he had overlooked some conditions necessary to be taken into the account for a complete explanation. M. ARAGO, however, entirely rejects the explanation of Mr. M'KEEVER, and it is fair to set down the terms in which he does so.

After having shown that the ground-gru cannot be explained by the action of the moon*, according to the sailors, nor by the friction of running water producing more heat at the surface than at the bottom, nor by referring its source to the smaller tributaries of the streams, nor to different layers of ice formed at the several surfaces, when the water in the river, from whatever cause, is in a state of varying fullness, all of which have been assigned as causes of the ground-gru, M. ARAGO proceeds:

"We come now to Mr. M'KEEVER, who, confining himself closely to the most subtle principles of the theory of heat, has not on this account been more fortunate than his predecessors. According to this author, 'the rocks, stones and gravel, which generally cover the bottom of rivers, have powers of radiation superior to those of mud, perhaps on account of their peculiar nature, but chiefly because they

* This explanation of the sailors is a confirmation of what I have stated, that the gru never appears but under a clear sky. The constant observation of the sailors has associated, in their minds, the shining of the moon with the ground-gru; but the moon never shines, to excite great attention, but in a clear sky.

have rough surfaces. Thus rocks in large or small masses will become much cooler in consequence of radiation: when the atmospherical temperature is very low, they of course freeze the water which touches them.' It is unnecessary to examine here whether heat radiates through a thick layer of water, as Mr. M'KEEVER supposes, as the most simple observation is sufficient to overthrow it. Where is the person who has not observed that the strong radiation, which the Irish philosopher admits, would be more plainly manifested, or as completely, in still water than in running water? but no one has seen a piece of still water frozen at the bottom*."

But there is nothing more easy of experimental proof than that heat radiates through water. I do not mean, however, to vindicate the reasoning of Mr. M'KEEVER respecting the more powerful radiation of it from stones than from mud. His reasoning respecting that matter is, on his own part, conjectural, to explain the readier formation of gru on a stony or gravelly bottom; but the gru also forms on a muddy bottom, a fact which M. ARAGO notices, when he brings the attachment of mud to the under side of the floating flakes as a proof that they have been formed at the bottom. Mr. M'KEEVER was driven to his conjecture from having overlooked the more complete and sudden inversion of the hydrostatic order that takes place over stones than over mud; which last is deposited only in places where the water has a stiller and more equable motion. In such places the ground-gru is later in forming, and therefore is more rarely seen; and it is doubtful whether Mr. M'KEEVER had a proper opportunity for noticing it in them.

But to return to the main point which we have here to maintain in opposition to the reasoning of M. ARAGO, the radiation of heat through a body of water. When we construct an achromatic object-glass for a telescope, it does not the less remain a burning-lens when we have included in it a transparent fluid, and no experiment has proved that were the fluid water the case would be altered. We are aware of the danger that has been incurred of setting fire to an apartment by an ornamental glass globe filled with water, and placed in the sun at a window. But as I cannot particularly refer to circumstances of time and place of the cases now mentioned, I made an experiment on the subject with such apparatus as I could find readily at hand, having no access to better in a remote country place†. In a room, of which the temperature was 50° FAHR., a semiglobular tumbler filled with water, containing about a pint and a half, was placed inside a window, in the rays of the low but clear winter sun. The bulb of a thermometer, which had been previously placed in a similar situation till it rose and remained steady at 61°, was shifted into the brightest part of the fan-shaped focus of rays, into which the light was refracted through the tumbler. In this position it was raised in four minutes to 72°. It was again shifted into the unconcentrated rays passing through the window, when it fell, but more

* Edinburgh New Philosophical Journal, vol. xv. pp. 132, 133.

† It may seem absurd to have had recourse to experiment in a case so plain; but the procedure seemed, at the same time, indispensable, to meet reasonings promulgated with the authority of such a distinguished name.

slowly than it had risen; and the experiment was repeatedly renewed with similar results, leaving no doubt that the heat, like the light, radiated through, and was refracted by the water. If the fact is so in regard to the radiation of heat through a mass of water four or five inches thick, where ought we to set the limits of thickness of the mass through which it cannot pass? Obviously only where the thickness is so great, that the aggregation of the fluid, and of its minute impurities, prevents the transmission of light, as in the deeps of the sea, but not within the ordinary depths of our clear streams.

Of the effect of radiation in cooling down the surface of the ground, and substances placed upon it, during a clear sky, we cannot give a more lucid account than that of M. Arago, in his paper "On the supposed Influence of the Moon on Vegetation." "No one had supposed," says he, "before Dr. Wells, that terrestrial substances, excepting in the case of a very rapid evaporation, may acquire during the night a different temperature from that of the surrounding air. This important fact is now well ascertained. On placing little masses of cotton down, &c. in the open air, it is frequently observed that they acquire a temperature 6°, 7°, or even 8° centigr. below that of the surrounding atmosphere..... These differences of temperature between solid bodies and the atmosphere only rise to 6°, 7°, or 8° of the centesimal scale, when the sky is perfectly clear. If the sky is clouded they become insensible." This lucid statement, however, requires one modification; for the greater cooling of the solid substances, under a clear sky, takes place not only during the night, but also during the day, in places not directly exposed to the sun's rays.

This radiation, as it passes freely through the transparent atmosphere, may, as we learn from the above experiment, pass also through the transparent water, to cool down the solid substances at the bottom below the temperature of the surrounding fluid. That fluid is permeable to radiating heat as well as the atmosphere. The application of the thermometer, in the hands of Dr. Wells, instructed us regarding the cooling of the surface of the ground; but the water of a river, placed under the very same condition of a clear sky, fluid above and freezing below, is a great natural thermometer, teaching us that a corresponding cooling is going on on the surface of the solid opake substances of the bottom. In fact, if we may so speak, the phenomenon of the ground-gru is the result of an experiment in the water, entirely similar to that of Dr. Wells on the land, performed by nature on a large scale, and presented to us for our interpretation and instruction. And when we look back to the observations made in the month of January, we find the results of the modifications of this great natural experiment corresponding with those of similar modifications of the experiment on the dry land.

The cooling of the surface of the ground by radiation, discovered by Dr. Wells, takes place only under a clear sky. It is therefore greatly modified on parts of the ground screened from a part of the sky by opake objects, as walls, trees, hedges. In illustration of the extent to which a screening or shading body, near at hand,

modifies the radiation, I shall detail some observations I made on the 7th of January last, incidentally in the first instance, but then extended, in reference to the observations on the ground-gru, which I was making at the time. Having occasion that day to dig into recently hoed ground, in the middle of a garden, remote from shade, the soil was observed to be frozen to the depth of four inches, by the clear frost, which had continued from the 1st of January, with the trifling intermission above mentioned. On digging into similar ground at the north base of a wall six feet high, the soil was found, close at the foot of the wall, frozen to the depth of only half an inch; at a foot distance from it, about an inch; at two feet, little more; and it was only at the distance of ten or twelve feet that it was frozen hard to the depth of three inches. A similar modification of the effect of radiation was observed in the shade of trees. Under the Scotch fir the soil, slightly covered with decaying herbage, was not at all frozen; although in similar ground similarly covered, but remote from shade, it was hard frozen to the depth of two or three inches.

Now the ground-gru in the rivers was modified in a way strictly similar by the effect of shade. The bridge of Alford, over the Don, is happily situated for illustrating this, being on one of the rapids, where the ground-gru is earliest and most abundantly formed. While the other rapids, and the unshaded parts of this one, were quite occupied by gru on both the 5th and 7th of January, spaces in the shade of the masonry at this bridge were quite clear of it. It cannot be admitted as an explanation of this fact, that heat may have been there laterally transmitted to the water by contact with the piers and walls; for if this took place, why then did the clear spaces on the bottom narrow gradually towards the low extremities of the embanking walls? Besides, the transmission of heat laterally had not hindered the formation of surface-ice, in contact with a pier, on a piece of still water under one of the arches. The modification of the radiation by shade was also exhibited in the absence of all gru on the bottom, along the foot of the dense tuft of Phalaris grass in the Leochal, where there could be no more transmission of heat laterally, than at the general line of the grassy banks of this stream.

The water, too, returning warmer from under the surface-ice, on the little pools at the edge of one of the rapids, is another instance of the modification of the radiation by shade. The thin white opake covering of hoar frost on the ice prevented radiation, at least in a great measure, and the heat of the bed of the river, in the course of continual transmission upwards, from strata not yet cooled to much depth by the frost, finding no outlet by the radiation, was expended in heating the water by contact.

There was another phenomenon observed on the 5th of January, (although no longer seen on the 7th, being then concealed by the immense formation of gru,) which can be readily explained by the admission of the radiation of heat through the water, and therefore goes to support the justness of the theory. The tufts of water starwort, in the deepest and stillest parts of one of the pools, were the darkest-

coloured objects seen at the bottom, and they were fringed in every part with spiculæ of gru, at a time while it yet occupied little of the bottom of this pool. The experiments of Boyle, Franklin, Rumford, Leslie (although he denies the conclusion himself), Davy, and Stark appear too uniform in their results to leave any doubt remaining, that dark-coloured bodies both absorb and radiate heat more freely than those which are light-coloured. It is in consistency, then, with an ascertained law of the radiation of heat, that the very dark-coloured tufts of the water starwort should have been the first bodies in the pool cooled to a very low temperature, and of course first covered with gru.

In arguing the whole question, let us not forget to assign a proper value to the illustrations of M. Arago. The first of them suggests a ready and satisfactory answer to one of the objections which he brings against the theory of radiation, which is, that the effect of it should be as readily manifested in still as in running water, and yet no one has seen a piece of still water frozen at the bottom*.

In still water, that hydrostatic order, which M. Arago has so well illustrated as belonging to water when reduced to a temperature under 39° Fahr., has free play to establish itself, and is not inverted by the mechanical action of a stream. When the temperature of a body of water is under 39°, then the coldest portions of it are the lightest, and naturally rise and float on the surface. When in a still pond the water nearest the bottom has been cooled below the general temperature by contact with the solid materials cooled by radiation, it is displaced by the heavier warmer water above. Hence ice forms first on the surface by the meeting there of both the cold of radiation and that acquired by contact with the incumbent cold atmosphere.

M. Arago's illustrations also furnish us with a satisfactory explanation of the curious facts, that the ground-gru makes its first appearance in the more rapid and agitated parts of the stream, and begins to show itself on the bottoms of the stiller parts, and to accumulate there in quantity, only after a longer continuance of the clear frosty weather. In the rapids the hydrostatic order is overturned, and the colder, which is also the lighter, water not only mixed with the warmer below, but, at the whirls of the greatest rapids, brought suddenly, without much mixing, into direct contact with the bottom, cooled still lower than itself by radiation. If the water is at the temperature of 32° Fahr. it can give out no heat to the colder bottom

* There is an exception to the universality of this position, which, although rare, I have sometimes witnessed; and as the phenomenon is in accordance with the theory of the radiation of heat from the bottom, it deserves notice. In little ponds of a foot or two deep, dug to obtain the materials for building or agricultural purposes, of which there are many examples in this neighbourhood, after they have been covered, owing to hard and long-continued frost, by a thick sheet of ice, that is sometimes nearly melted off, and the remaining fragments driven to the lee side by a strong westerly gale of high temperature. Such a gale, in this climate, frequently, towards its conclusion, shifts to N.W., when the temperature of the air falls again below the freezing-point of water, with a generally clear sky. In such peculiar circumstances the little ponds are suddenly filled with gru, commencing at, and shooting up from the bottom. The whole water is here at 32° Fahr. when the gru begins forming, and the hydrostatic order is deranged by the wind.

without part of it being converted into ice, the spiculæ and crystals of which find a solid body for their attachment at the very point where the heat is given out*.

But while in this manner we can explain some of the incidents, may it not be held, as above demonstrated, that the chief cause of the ground-gru is the radiation of heat from the bottoms of the rivers? Every branch of the phenomenon is of easy explanation when we admit the radiation; and among the rest a circumstance to which I have yet made no reference, and that is, the disappearance at the bottom of the water of the immense quantity of heat, 140° of FAHR., which constitutes the caloric of fluidity disengaged, when water at 32° FAHR. is converted into ice at the same temperature.

The answer to our original question then is, That ice is formed sometimes on the surface of running water, and sometimes at the bottom, because frost sometimes takes place with a clouded sky, which is incompatible with radiation of heat from the bottom of the stream, and sometimes with a clear sky, when that radiation takes place through the water, in the same manner as the experiments of Dr. WELLS prove it goes on, under a like sky, through the atmosphere. The bottom is by this cooled down below the freezing point of water, before the water itself; ice is formed on it, and its detachment by transmitted heat from below prevented, as long as the radiation continues.

* We may observe also, that there is a local source of greater cold of the water in the rapids, in its being brought into more active and extensive contact with the air by the sharp ripple and spray.

XIX. *Observations on the Theory of Respiration.* By WILLIAM STEVENS, *M.D. D.C.L. Fellow of the Royal College of Physicians in Copenhagen, Fellow of the Royal College of Surgeons in London, &c. &c. Communicated by* W. T. BRANDE, *Esq. V.P.R.S.*

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THE cause of the dark colour of the blood in the venous circulation has long been a subject of discussion; but even at the present moment the question has not been satisfactorily decided.

It is universally admitted that the expired air contains carbonic acid, but it is still doubtful in what part of the system this acid is formed. LAVOISIER maintained that carbon was the cause of the dark colour of the venous blood, and that the acid was formed in the pulmonary organs, by the combination of that carbon with the oxygen of the air. At one period this theory was generally adopted, though the evidence in its favour is almost entirely hypothetical; for hitherto there has not been even one well-conducted experiment which proves the existence of any form of free carbon in the venous blood.

Another class of physiologists maintain that the carbonic acid is formed, not in the lungs, but in the general round of the great circulation; in proof of which some experimentalists have asserted that they had obtained carbonic acid from venous blood; but others, of equal respectability, who have repeated the same experiments, deny the existence of this acid in the venous current. The air-pump has hitherto been almost exclusively used for the purpose of deciding this question; but the positive proofs which have been brought forward by the one class of physiologists have been so completely contradicted by the negative proofs of the other, that a great majority remains still in favour of the old theory. In fact, TIEDEMANN and GMELIN, the latest writers on this subject, are decidedly of opinion that venous blood does not contain carbonic acid. As this is a very important question, the following experiments were made in reference to it.

1. A glass vessel containing a small quantity of warm and fluid venous blood was put under the receiver of an air-pump. In proportion as the air was exhausted, a number of globules appeared to escape from the blood, which were at first small, but in proportion as the air was removed they became larger in size.

2. A small quantity of venous blood, contained in a glass vessel, was covered with a layer of barytic water. This was put under the receiver of an air-pump. When the

pump was used, globules were observed to escape from the blood, which passed through the barytic water, but the transparency of the latter was not affected.

The annexed sketch is a representation of an apparatus which was invented by Mr. Squire, of Duke Street, Grosvenor Square, and used in the following experiments. To a double-necked pint bottle, *a*, two glass tubes were fitted, one, *b*, ascending, the other, *c*, descending. The ascending tube is terminated by an air-tight box, having an aperture, over which a slide is moved by means of a strong wire. The descending tube is terminated by a brass orifice, which is closed at pleasure by a brass cap, having a cone in the centre surrounded with leather, and moved with a sliding wire. *d* represents a four-ounce phial with a loop of wire round the neck, by which it is connected with the descending tube. The phial was filled to the double line with distilled water.

3. The pint bottle and both tubes being filled with pure hydrogen gas, the orifice of the upper tube was placed on the skin, near the bend of the arm; a vein was then opened, and the orifice slid carefully along until it included the incision which had been made by the lancet. The valve was opened, and as the blood passed into the bottle, hydrogen was expelled through the descending tube, the orifice of which was immersed in distilled water. As soon as five or six ounces of blood had entered the bottle, both the orifices were carefully closed. The orifice of the descending tube was then immersed in barytic water, and the valve being opened, the whole was placed under the receiver of an air-pump. In proportion as the air was removed, the hydrogen, as well as any gas that might escape from the blood, passed through the barytic water, without, however, producing the slightest change in its transparency.

From the first of these experiments it might be inferred that a gas is capable of being removed from venous blood by the air-pump: but this supposition may possibly be erroneous; for similar globules appear to arise when we use water, even after it has been boiled and then cooled in a close vessel to 98°. The second experiment shows that this appearance is not due to the escape of carbonic acid; and from the third experiment it is very obvious that carbonic acid cannot be so obtained from venous blood which has not been exposed to air.

4. About four ounces of serum were put into a Hope's eudiometer, the upper division of which contained four tenths of a cubic inch of carbonic acid: they were agitated together, and after a few minutes the serum had absorbed the whole of the acid. This impregnated serum, without being exposed to the air, was transferred into the double-necked pint bottle, which had previously been filled with hydrogen, and which was immediately put under the receiver of the air-pump. When the pump was used, the hydrogen, as well as the gas which appeared to escape from the serum, passed through the barytic water; but its transparency was not affected.

From this experiment it is obvious that serum (consequently blood or other albuminous fluid,) may absorb carbonic acid, and so retain it as not to be separable by the mere removal of the pressure of the air.

The air-pump has hitherto been used almost exclusively by the experimenters on venous blood; and those who deny the existence of carbonic acid in it, do so almost entirely on such evidence. The fact of their not having thus obtained this gas is correct; but there is an error in the conclusion drawn from it, which is the chief cause of the difference of opinion on this subject; for such experiments only afford a positive proof that carbonic acid cannot always be obtained from blood placed under the exhausted receiver of the air-pump: but, with respect to the existence or non-existence of such acid in the blood, the proof is merely negative; for in experiment 4. the pump did not separate carbonic acid from serum previously impregnated with it: consequently such experiments are inconclusive.

5. Carbonic acid was introduced into an empty bladder that had been previously well moistened with warm water. When the bladder was distended about one third, its neck was firmly tied with a waxed thread, by which it was suspended in the centre of a receiver of an air-pump. When the pump was worked, the bladder increased in volume, and in a few seconds was much distended. Nearly the whole of the atmospheric air was exhausted from the receiver, but the bladder, though apparently very tense, did not burst, neither did it decrease in size. A shallow glass vessel containing barytic water had been placed under the same receiver, but the transparency of this was not affected. Hydrogen was then transmitted into the receiver, and the bladder was reduced to the same size as when first suspended under it; but, after an interval of four hours, it had become perfectly flaccid. In fact, there was scarcely a particle of carbonic acid left in it, and the barytic water within the receiver contained a quantity of carbonate of baryta.

6. The double-necked bottle was carefully filled with pure hydrogen, and about five ounces of blood were drawn into it from a vein in the arm, in the same manner as in experiment 3. Both the orifices of the bottle were then closed, and the blood and the hydrogen well agitated together. After this the lower orifice was immersed in distilled water, and the bottle left undisturbed for nearly an hour, to allow the hydrogen to act on the blood. The orifice of the descending tube was then immersed in barytic water, the lower valve was opened, and the whole apparatus put under the receiver of the air-pump. When the pump was used, the gas which was over the blood passed through the barytic water, and immediately rendered it turbid. This experiment seems to prove that venous blood does contain carbonic acid; and as the only difference between experiments 3 and 6 was, that in the former the pump was used *immediately*, and before the hydrogen had time to act on the blood, whilst in the latter the hydrogen was allowed to act nearly an hour, it would appear that the hydrogen has some power of removing the carbonic acid, and that this removal may even take place through a membrane. In the last experiment, the blood which was

used had been carefully excluded from atmospheric air, and the hydrogen was pure; consequently the carbonic acid could have been derived from no other source than the venous blood itself.

7. A few ounces of venous blood were drawn into a double-necked bottle previously filled with hydrogen. After having been gently heated, the hydrogen was found to contain carbonic acid. This experiment was made at Copenhagen in the beginning of 1833, by Professor FORCHAMMER and myself; but the conclusion which we drew from it respecting the existence of *carbonic acid* in the blood was by some objected to, in consequence of the interference of *heat*: the air-pump experiments, however, remove all such objections.

Dr. EDWARDS confined some animals in an atmosphere of hydrogen, and they continued to live for a considerable period, during which it was found that the hydrogen had acquired a portion of carbonic acid, which in some cases was equal in bulk to the size of the animals. By some these experiments were considered as conclusive of the evolution of carbonic acid from venous blood; but others maintained that there might have been a sufficient quantity of oxygen in the pulmonary cells to account for the formation of the carbonic acid. This objection is also removed by the above experiment.

Dr. MITCHELL of Philadelphia made an experiment in 1830 with hydrogen and venous blood, but without obtaining any carbonic acid. Mr. G. H. HOFFMAN of Margate made a similar experiment in 1832, and obtained a sufficient quantity of carnic acid, not merely to render lime water turbid, but even to render the hydrogen uninflammable. These contrary results seem to me to have arisen from Dr. MITCHELL having used the air-pump *immediately*, and before the hydrogen had time to act on the blood so as to displace its carbonic acid; whereas Mr. HOFFMAN agitated the hydrogen with the blood, and probably allowed a sufficient time for their mutual action.

8. A small quantity of venous blood was drawn into the double-necked bottle, containing atmospheric air, the valve at the orifice of the ascending tube was closed, and the orifice of the descending tube was immersed in barytic water. The bottle was put under the receiver and the pump immediately used. But in this experiment the barytic water was not more affected than it would have been by a similar quantity of common air. This proves that when the blood is exposed even to common air, carbonic acid cannot be obtained, when the pump is used immediately, and before any change of colour in the blood has taken place; that is, before the air has had time to act upon it.

9. A small quantity of blood was drawn into the double-necked bottle containing atmospheric air, as in the last experiment. Both of the valves were closed, and *after agitation, the bottle was allowed to stand about an hour, during which the colour of the blood changed from venous to arterial.* The lower orifice was then immersed in barytic water, the apparatus was put under the receiver of the air-pump, and when the pump was used, the gas which escaped *gave a milky appearance to the barytic*

water. In the eighth experiment the pump was used immediately, and before the air had time to act on the blood, or the blood on the air. In the last, one hour was allowed for the action of these agents upon each other; during which the blood on the surface changed from venous to arterial, and the air over the blood received the addition of carbonic acid.

Those who maintain that carbonic acid is *formed* in the lungs will say, that in the last experiment the carbon of the blood attracted the oxygen of the air, and that the carbonic acid so formed was then evolved. But there is one circumstance which is I think fatal to such an explanation, for all the acids blacken the blood, and carbonic acid possesses this blackening property in a remarkable degree. When we agitate a small quantity of carbonic acid gas with arterial blood, the colour immediately changes to venous, and when we add carbonic acid to venous blood it becomes almost black. Now, if the carbon of the blood attracted the oxygen of the air, and if the carbonic acid were thus formed in the blood itself, it is evident that the *first* effect of the air on the blood would be to make this fluid blacker than it had been before; but the opposite of this is the fact, for the *first* effect of the air is, not to blacken, but to brighten the blood; consequently, from this alone, we may infer, that the acid is not formed during the experiment, but that it exists ready formed in the blood, and that it is only removed, and not produced or formed, by the atmospheric air.

I have already observed that one class of experimenters have obtained results by means of the air-pump which are in direct opposition to those obtained by others. May we not now, from the above experiments, explain this difference by supposing that those who could not obtain carbonic acid made their experiments before the air had had time to act on the blood, whilst the others had allowed some time to elapse?

From the preceding statement we may, I think, conclude,

1st, That venous blood contains carbonic acid;

2nd, That the mere effect of diminished pressure upon the surface of the blood is not necessarily followed by the escape of its carbonic acid*.

We have seen in some of the above experiments that atmospheric air possesses a property of removing carbonic acid from venous blood; it becomes therefore a question how this effect is produced. I have ascertained that nitrogen is ineffective; we may therefore infer that the oxygen is the principal agent; and that such is the fact is proved by the following experiments.

10. A piece of moist bladder was tied firmly over the mouth of a tumbler containing pure oxygen gas. This was introduced into a large bell glass filled with carbonic acid. In a short period the membrane which had been tied over the glass became convex, and so tense that it appeared to be on the point of bursting. On examining the air contained in the tumbler, it was found that the oxygen had drawn in a large

* In performing the above experiments I was assisted by Mr. Squire, to whom I feel under great obligation for the zealous and able manner in which he aided me in the whole of the present investigation.

quantity of the carbonic acid; but no oxygen appeared to have passed out of the tumbler.

11. A piece of moist bladder was tied over the mouth of a tumbler containing carbonic acid; this was introduced into a bell glass filled with pure oxygen. In a short period the membrane became concave, and the oxygen in the larger vessel was found to be mixed with carbonic acid.

These two experiments prove that oxygen possesses the power of attracting carbonic acid, even through the medium of a membrane which is much denser than that interposed in the lungs betwixt the air and the blood; consequently, the extreme delicacy of the pulmonary membrane can be little impediment to the transmission of carbonic acid in the process of respiration.

I have ascertained that such transmission, or, in other words, the peculiar power by which oxygen abstracts carbonic acid from the blood, is more energetic in a high than in a low temperature. Hence venous blood drawn in a warm room changes colour more rapidly than blood drawn in a cold atmosphere.

12. A few ounces of venous blood were drawn into the double-necked bottle which had been previously filled with pure oxygen; the valves were closed, the blood was well agitated with the gas, and the colour immediately changed from venous to arterial. The bottle was allowed to stand about half an hour, and was then placed under the receiver of an air-pump. When the pump was used the oxygen was found to be strongly impregnated with carbonic acid; in fact, the first bubbles of air which passed through the barytic water rendered it milky.

From the rapidity of the change of colour from venous to arterial, or from dark to florid, in this experiment, it seems very improbable that any carbonic acid should have been *formed* in the blood, but that, on the contrary, it had previously existed in the blood, and that the whole of this blackening gas had been instantly removed by the oxygen.

13. A piece of the intestine of a rabbit that had been recently killed was filled with *carbonic acid*, and suspended in a bell glass containing *oxygen*. In a short period the acid escaped, and the intestine became quite flaccid.

14. A piece of intestine, similar to that used in the last experiment, was filled with *oxygen*, and suspended in a bell glass of *carbonic acid*; the intestine began to swell almost immediately, and in three minutes it burst.

15. The *lung* of a rabbit was filled with oxygen, and suspended in a bell glass of carbonic acid; it began to swell almost instantly, and in one minute it burst.

16. The *lung* of a rabbit was carefully inflated with carbonic acid, and was then suspended in a bell glass of oxygen. In a very short period it became flaccid, and the external oxygen was impregnated with carbonic acid.

These experiments show how admirably the structure of the lungs is adapted for the action of oxygen on carbonic acid. Vitality may have some share in accelerating this process in the pulmonary organs, but we know that by the agency of oxygen

dead blood may be changed from venous to arterial, even through a dead membrane.

This power which gases possess of acting on each other is in some respects similar to that which takes place in fluids, and which has been described by DUTROCHET under the name of *endosmosis* and *exosmosis*. In the experiments detailed by this philosopher the intervening septum is supposed to contribute materially to the phenomena. In the experiments with gases the intervening membrane does not prevent, but it does not contribute to, the change. But independent of this, the existence of this power in gases was not known to DUTROCHET until after the fact had been fully ascertained by others. Mr. DALTON many years ago proved that hydrogen possessed the power of penetrating or mixing with carbonic acid in opposition to gravity; that oxygen possesses the same property, but in a higher degree, I ascertained in the island of St. Thomas in 1827. I afterwards made experiments on a larger scale, in 1830, at the high rock of Saratoga, where there is an atmosphere of natural carbonic acid; and the result was communicated to many physicians in America previously to any of the American publications on the subject.

It is now more than probable that the changes which LAVOISIER believed to occur in the lungs take place in reality in the extreme circulation. Some later writers have assumed that the elements of carbonic acid exist in the blood, and that its formation commenced in the large vessels as they leave the left side of the heart, and was not finally completed until the blood arrives in the right auricle. But that this opinion is erroneous, is evident from the fact, that the blood even in the smallest arteries is as completely *arterial* as that in the left side of the heart, whilst the blood in the smallest veins is equally *venous*.

There is in the capillary system, over the whole body, an intermediate structure which connects the arterial with the venous circulation, and it is in this structure that the blood is changed from arterial to venous. When the arterial blood leaves the minute arteries, it is no longer confined in actual vessels, but in cells that are formed by the surrounding tissue. When this cellular structure is examined in living animals, with the assistance of a good microscope, minute globules are seen to leave the cells and penetrate the surrounding solids, whilst other globules are seen to return and mix with the blood in the cells. Now as we know that it is in these cells that the blood becomes dark and venous, from the addition of carbonic acid, may we not suppose that the globules which leave the blood are minute particles of oxygen, attracted perhaps from the arterial blood by the fixed carbon of the solids, and that the globules which return are minute particles of carbonic acid? This cannot be easily proved; but as carbon is a principal ingredient in the solids when these are converted into fluids, previous to their removal by the lymphatics, it appears to me not improbable that a part of their carbon may be liberated, perhaps for the purpose of evolving heat. We have seen that the blood which receives oxygen in the lungs passes unchanged through the arteries into the capillary system; and it is ap-

parently there that animal heat is evolved. When carbonic acid, which is the result of the above process, is added to the venous blood, it not only blackens the colour, but renders it incapable of supporting life. For this reason warm-blooded animals have a double circulation, one for circulating the arterial, and another for purifying the venous blood*.

When we obtain *hæmatosine*, or the colouring matter of the blood, in a pure state, it is black; but a solution of any neutral salt possesses the peculiar property of striking a beautiful scarlet or arterial colour with it. When we make an incision into a clot of blood which has just coagulated, we find that the clot is then all equally red: when we cut out a thin slice of this red clot, and immerse it in distilled water, the salt serum oozes into the water. In proportion as this takes place the clot becomes darker; and when the whole of the serum is removed, perfectly black. When in this state neither atmospheric air, nor even pure oxygen, is capable of changing its colour; but when we immerse this black clot in a clear saline solution, it instantly changes from jet black to a scarlet, or arterial colour. From these facts we may conclude, that oxygen is a secondary agent in the change of colour from venous to arterial; and that if the scarlet colour of the blood be essential to life, it is produced, not by oxygen, but by another cause. The mere removal of the carbonic acid from venous blood would not produce any change of colour, were it not that there is in the blood itself another agent which produces the arterial tint, the moment that the blackening effect of the carbonic acid is removed: this is effected by the action of the natural saline ingredients of the blood on the colouring matter. When oxygen is added to blood it may have a slight share in brightening the colour, but it can only perfectly effect this when the colouring matter is in contact with a saline fluid. Oxygen is so far from being the sole cause of the arterial colour, that even pure oxygen is *of itself* inert as a colouring agent; whilst a saline fluid changes the colour of the blood from venous to arterial even in an atmosphere of carbonic acid.

Many authors describe the changes which occur in respiration, by asserting "that oxygen disappears, and carbonic acid is emitted." But from some of the experiments which I have detailed, it is evident that the removal of the acid is the first part of the process, and the addition of oxygen the last. Others have maintained that when

* It is well known that cold-blooded animals use very little food. If a rattlesnake gets one good meal in three months, it is all that he requires: but even this is not actually necessary; for I have seen one of these animals that had not tasted food or water for twelve months, as plump, active, and venomous as those in the wild state. On the other hand, all those animals that have warm blood require an immense quantity of food, and if they do not receive this they soon perish; but nineteen twentieths of this appears to be taken into the system for the evolution of animal heat. The carbon is ultimately derived from the nourishment that we use, and the oxygen is directly derived from the arterial blood: a constant supply of nourishment is therefore necessary in warm-blooded animals, but a very small part of the blood which is formed from this is required for nutrition, and if the whole of it were expended in this way, it is very clear that there would be none left to return by the veins.

two gases act upon each other, the one penetrates the membrane at the same moment that the other is removed. But if this were the case, why did the membrane become *convex* in experiment 10, and *concave* in experiment 11? If the action were equal, the membrane would remain unchanged; but this is so far from being the case, that in some experiments the membranes became distended to such an extent that they actually burst.

It was supposed by Spallanzani, and afterwards by Dr. Edwards, that in the process of respiration the carbonic acid was merely exhaled from the lungs. We have seen, however, that venous blood so retains that acid that it cannot be removed, even with the aid of an air-pump; consequently, were there not an active agent for the purpose of removing the carbonic acid from the venous blood as it circulates through the lungs, it would remain unchanged, and almost instantly cause death. It is the power which oxygen possesses of attracting carbonic acid, which renders oxygen essential to life. As hydrogen also possesses this power, it supports life for a longer period than most of the other gases; but hydrogen has a deleterious effect on the blood; and when animals are forced to breathe it, though the carbonic acid is removed, a part of the hydrogen is at the same time absorbed, which blackens the blood, and the animals soon die.

The property which oxygen possesses of attracting carbonic acid, furnishes the following explanation of the process of respiration. When the venous blood arrives in the lungs, the oxygen of the atmosphere is, in the first instance, the active or attracting agent. It removes the carbonic acid, which had been the cause of the dark colour of the blood. When this is removed, or perhaps in proportion as it is removed, the blood becomes the attracting agent, and a portion of oxygen is attracted into the blood, and takes the place of the carbonic acid. From the peculiar structure of the lungs, these changes are rapidly effected, particularly at the high temperature of 98°; and when the process is fully completed, we know from the great discovery of Harvey, that the blood which has received the pure air passes rapidly on to the arterial, and from this again to the capillary system.

If the above theory be correct, it follows that the blood is converted from arterial to venous in the extreme circulation, by the loss of oxygen and the addition of carbonic acid; whilst the venous blood is converted into arterial, by the loss of carbonic acid, and the addition of oxygen; consequently, the essential difference betwixt venous and arterial blood is, that the former contains carbonic acid, and the latter oxygen.

I have said that black is the natural colour of the colouring matter; but when this agent is diffused in a saline fluid, such as the serum, it is of a bright scarlet tint, which is, in fact, the natural colour of arterial blood. When carbonic acid is added to this blood in the extreme circulation, it becomes dark red; but when this acid is removed in the pulmonary organs, the blood then resumes its natural scarlet or arterial colour; and this, as I have said, is produced not directly by oxygen, but chiefly, if not entirely, by the action of the salts of the blood on the colouring matter.

Oxygen, it is true, changes the colour from venous to arterial; this, however, is effected not by any specific action, but by the removal of the carbonic acid, which had been the cause of the dark colour in the venous circulation.

Many objections have been made to the above theory, some of which are frivolous; but there are two which are worthy of notice. The first was made by Mr. PRATER of Edinburgh, who stated, that according to this theory the blood ought to become *arterial* under the exhausted receiver of the air-pump. This objection is removed by the foregoing experiments, which prove that the mere removal of the air's pressure is insufficient to overcome the attraction that subsists between the carbonic acid and the blood. The second objection was made by Dr. GREGORY and Mr. IRVINE of Edinburgh. These gentlemen admit that if the blood were a stronger saline fluid than it is, the salts would be capable of producing all the effects described; but they conceive that the blood is not sufficiently impregnated with saline matter to account for the whole of the phenomena. This objection, even if proved, would only require a modification of the theory; but that there was a fallacy in their experiments which neutralized their conclusion, has been proved by a paper in the Medical Gazette of the 12th of April, 1834.

XX. *Discovery of the Metamorphosis in the second type of the* Cirripedes, *viz. the* Lepades, *completing the Natural History of these singular Animals, and confirming their affinity with the* Crustacea. *By* J. V. Thompson, *F.L.S. Deputy Inspector-General of Hospitals. Communicated by Sir* James Macgrigor, *Bart. M.D. F.R.S.*

Received January 3,—Read March 5, 1835.

THE Fourth Memoir, published in my Zoological Researches and Illustrations, No. III. page 69, &c., having first made known the real nature of the *Cirripedes*, the key of which remained concealed in their metamorphosis, it might have been expected that some naturalist favourably situated to investigate the oceanic tribe of these animals, would have been the first to make the same discovery in regard to these, and thereby complete their natural history. It was scarcely to be expected that the honour of this discovery also should be reserved for the author, fixed to one spot, where none of them naturally exist, and are but casually thrown upon our shores by the waves of the Atlantic, attached to pieces of wreck, or brought into port fixed to the bottoms of ships returning from distant voyages. Fortunately, however, two ships of this description came into this harbour (Cork), one from the Mediterranean, the other from North America, which, not being sheathed with copper, had their bottoms literally covered with Barnacles of the three genera of *Lepas*, *Cineras*, and *Otion*; and having persons employed expressly for the purpose, numbers of these were brought alive in sea water, amongst which were many with the ova in various stages of their progress, and some ready to hatch, which they eventually did in prodigious numbers, so as to enable him to add the proof of their being, like the *Balani*, *natatory* Crustacea *in their first stage*, but of a totally different facies and structure; a circumstance which determines the propriety of the separation of the *Cirripedes* into two tribes, and evinces the sagacity of Mr. MacLeay in being the first to indicate that these two tribes, the *Balani* and *Lepades*, were not so closely related as generally supposed *.

The larvæ of the *Balani*, described in Memoir IV. under the external appearance of the *bivalve Monoculi* (*Astracoda*), have a pair of pedunculated eyes, more numerous and more completely developed members, approximating to those of *Cyclops*, and of the perfect *Triton*; while, in the present type, or *Lepades*, the larva resembles somewhat that of the *Cyclops*, which Müller, mistaking for a perfect animal, named *Amymone*, and which can be shown to be common to a great many of the *Entomostraca*;

* See Horæ Entomologicæ.

or the resemblance is still more striking to that of the *Argulus Armiger* of Latreille, which, in fact, is but an *Amymone* furnished with a tricuspidate shield at the back.

The genus *Cineras* was the first in which the larvæ were observed to hatch, July 27, three days after the arrival of the ship; then in *Lepas anserifera*, August 19; and a few days later in *Lepas dentata*; in all of which there is a perfect accordance, with very slight differences, which probably resulted from the more or less perfect development of the larva. The very remarkable and beautiful one of *Lepas anserifera* may be regarded as the perfect type to which all the others are to be referred (fig. 5.).

In the whole of this tribe of the *Cirripedes*, the ova, after expulsion from the ovarium, appear to be conveyed by the ovipositor into the cellular texture of the pedicle, just beneath the body of the animal, which they fill to the distance of about an inch. When first placed in this situation they seem to be amorphous, and inseparable from the pulpy substance in which they are imbedded; but as they approach to maturity, they become of an oval shape, pointed at both ends, and are easily detached. Sir Everard Home has given a very good representation of them, at this stage of their progress, in his Lectures on Comparative Anatomy, from the elegant pencil of Mr. Bauer.

During the stay of the ova in the pedicle, they render this part more opake, and of a blueish tint; the ova themselves, and the cellular texture with which they are surrounded, being of a pale or azure blue colour. It is difficult to conceive in what manner the ova are extricated from the situation above indicated; but it is certainly not by the means suggested by Sir Everard Home in the above-mentioned Lecture, viz. by piercing outwards through the membranes of the pedicle, for the ova are subsequently found forming a pair of leaf-like expansions, placed between either side of the body of the animal and the lining membrane of the shells in *Lepas* (fig. 1.), or of the leathery internal tunic in *Cineras*. These leaves have each a separate attachment at the sides of the animal to the septum, which divides the cavity occupied by the animal from that of the pedicle: they are at first comparatively small, have a rounded outline, and possess the same blueish colour which the ova had in the pedicle; but as the ova advance in progress these leaves extend in every dimension, and lap over each other on the back, passing through various lighter shades of colour into pale pink, and finally, when ready to hatch, become nearly white (fig. 2.). These leaves appear to be composed of a layer of ova irregularly placed, and imbedded in a kind of parenchymatous texture, out of which they readily fall when about to hatch, on its substance being torn asunder; indeed, it appears at length to become so tender as to fall entirely away, so that after the period of gestation is past, no vestige of these leafy conceptacles is to be found.

When the larvæ, barely visible to the naked eye, burst forth from the ova, their development goes on with such rapidity that they seem to grow sensibly while under observation. These changes have been depicted in *Cineras* at figg. 6. 7. & 8., which

last probably did not possess sufficient vitality to pass into the next stage, such as we see that of *Lepas anserifera* (fig. 5.).

The larva of the *Lepades*, then, is a tailed *Monoculus*, with three pairs of members, the most anterior of which are simple, the others bifid, having its back covered by an ample shield, terminating anteriorly in two extended horns, and posteriorly in a single elongated spinous process*.

It must ever remain uncertain how long the larvæ of the *Lepades* remain in their first or free state, but it is probably for a longer or shorter period of time, according as they sooner or later meet with a substance adapted to their respective habits: thus, those of the *Lepas fascicularis* attach themselves in preference to Gulf-weed or floating *Fuci*; *Lepas minima* to slender species of *Antipathes*; *Lepas anserifera*† and *dentata*, *Cineras vittatus*, and *Otion*, to the bottoms of ships; *Lepas anatifera*‡ to floating timber, and to one another; while *Lepas sulcata* seems to prefer the backs of Turtles and the shell of the *Ianthina*: the species, however, have not been sufficiently discriminated, nor observations of this kind made with the requisite care, to enable us to prosecute further this part of their natural history. It is evident that they possess locomotive powers which enable them at every instant to change their situation, and a conspicuous eye to guide them in their choice.

These remarkable and important discoveries, connected as they are with those relating to the *Crustacea*§, complete the natural history of this tribe, and lead us to the following important results, viz.

I. That the *Cirripedes* do not constitute *a distinct class* of animals, as they have been considered by all late naturalists, Dr. Leach, Latreille, Lamarck, Cuvier, &c., being connected with the *Crustacea decapoda* through the *Balani*, and with the *Entomostraca* by means of the *Lepades*.

II. That they have no relation or affinity whatever with the *Testacea*, as supposed by Linnæus and all the older systematists.

III. That the *Crustacea* now therefore furnish examples of a class in which we have animals free and fixed, with eyes and eyeless, and with the sexes separated in some and united in others, all of which are characters to which naturalists have attached the greatest importance as regards classification.

IV. That the proof of metamorphosis being fully and satisfactorily established, tends still to maintain the affinity so long recognised between the *Crustacea* and *Insecta*.

Note.—The same economy in regard to the disposal of the ova has been observed in *Otion*, but hitherto no individual has been found with the ova on the point of hatching.

* Compare with the larva of *Artemis* (Brine Shrimp). Zoological Researches, No. v. Plate II. f. 7, 8. (herewith sent).

† Philosophical Transactions, vol. i. Plate xxxiv. fig. 5.

‡ Philosophical Transactions, vol. i. Plate xxxiv. fig. 6.

§ Zoological Researches, Memoir I. and Addenda, p. 63.

PLATE V.

Fig. 1. *Lepas anserifera*, opened from behind to show the first stage of the leaf-like conceptacles of the ova (*m*).

a. Animal.

o. Ovipositor.

v. Valves.

p. Pedicle.

Fig. 2. Another individual, showing the conceptacles in an advanced stage, the right conceptacle being turned back (*m*).

Fig. 3. A portion of the conceptacle magnified.

Fig. 4. An ovum ready to hatch.

Fig. 5. Fully developed larva of *Lepas anserifera*, viewed in front, highly magnified.

Fig. 6. Larva of *Cineras vittatus*, just excluded from the ovum.

Fig. 7. The same more developed.

Fig. 8. The fully developed larva of the same, viewed in front and highly magnified.

Fig. 5.

Fig. 2.

Fig. 4.

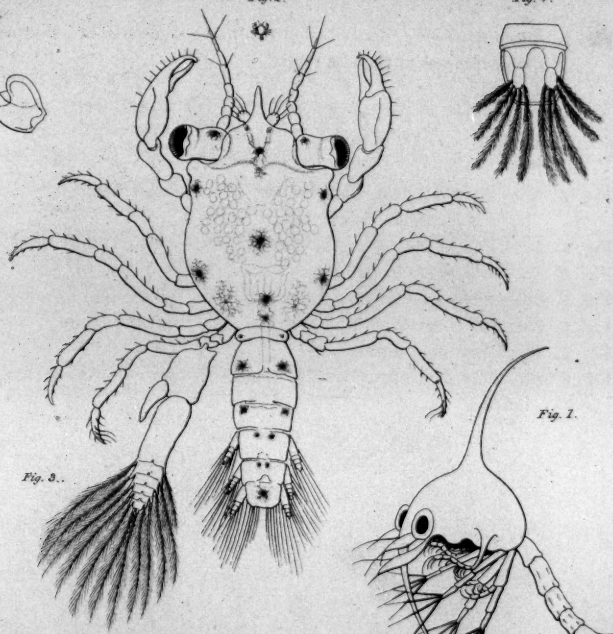

Fig. 3.

Fig. 1.

Fig. 6.

J. Basire sc.

XXI. *On the Double Metamorphosis in the Decapodous* Crustacea, *exemplified in* Cancer Mænas, *Linn.* *By* J. V. Thompson, *F.L.S. Deputy Inspector-General of Hospitals.* *Communicated by Sir* James Macgrigor, *Bart. M.D. F.R.S.*

Received May 21,—Read June 4, 1835.

In the Memoir published in my Zoological Researches, p. 1, with its sequel, p. 63, having first made known the fact of the *Brachyura* of the *Decapoda* (Crabs) passing through the intermediate form of *Zoea*; I have now to announce that they undergo another metamorphose, no less singular and unlooked for, in which they assume the form of the genus designated by the name of *Megalopa* by Dr. Leach, from the disproportionate size of the eyes. This second stage we may therefore consider analogous to that of pupa in the class *Insecta*.

By the former memoir it appears that the young of *Cancer Pagurus*, the common market Crab, first presents itself as a *Zoe* *, and that a full-grown *Zoe* was observed passing into some other more perfect form †, which at that time was considered to be that of some species of Crab: the discovery now first detailed, however, shows that it must have been only passing into that of a *Megalope*.

The first proof I had of this new and extraordinary fact, which cancels another anomalous genus of the *Crustacea*, was obtained by keeping in regularly renewed seawater a number of individuals of a *Megalope* ‡ which makes its appearance in the river Lee, just below the city of Cork, in considerable abundance every summer: these, to my very great surprise, began, after a short time, to change into a minute Crab §, until the whole of them, to the amount of about two dozen, were so metamorphosed. I have frequently since observed the same circumstance, and came to the conclusion that these must be the progeny of the only Crab that is ever found in the higher parts of the river, where these *Megalopæ* were taken, viz. *Carcinus Mænas*, our common Shore Crab. The young Crab, it will be noticed, has not the distinctive characters of its parent, which it probably acquires only after several casts of its shelly covering.

To complete the series of metamorphoses in this species of Crab now became a matter of research; and I have been so fortunate as to succeed in hatching its mature spawn, so as to be enabled to give a representation of its *Zoe* ‖, or first stage, and thereby render complete its natural history. In this stage it does not appear to differ materially from that of *Cancer Pagurus*, formerly figured in Zoological Researches

* Pages 9 and 64. † Page 8. ‡ Fig. 2. § Fig. 6. ‖ Fig. 1.

Pl. VIII. fig. 1. It is, however, certainly much smaller, and of a greenish tinge, with a few darker spots.

If the above facts do not warrant the conclusion I have drawn, what other proof can be required? Is it necessary that the young Crab should be traced through its subsequent changes until the character of the species becomes more apparent? or that the grown *Zoe* should be actually seen to change into a *Megalope*? Neither of these is impracticable, but may yet for a long time elude the most zealous and scrutinizing observers.

It appears, then, that the animals of this division of the *Crustacea* not only undergo metamorphosis, as formerly stated, but that they even undergo a double metamorphosis, being hatched from the ova under the singular and grotesque form of *Zoea*, then assume that of *Megalopæ*, and finally that of their parent Crab. How long they remain in each of these two intermediate states it may be difficult to determine with exactitude; but judging from the very considerable size of the *Zoe* I observed about changing its condition *, compared with their very minute size when first hatched, and also from *Megalopæ* not appearing before May or June, while *Zoea* are seen so early as March and April, I think a month may be assigned as the probable duration of the *Zoe* stage. The other, or *Megalope* stage, is less within the scope of observation; but as there is not that very great disparity of size between young and full-grown *Megalopæ*, it is likely that it does not exceed half that of the former.

If further proof of this double metamorphosis be desired, I have been so fortunate as to trace it, but not in quite so satisfactory a manner, in one of the Swimming Crabs, or *Portuni*, and also in *Inachus*, belonging to the section of Triangular Crabs. These examples, derived from some of the principal groups of the *Brachyura*, may be supposed quite sufficient to satisfy the most scrupulous, as to their metamorphosis; I propose, however, in future memoirs, to bring under the notice of the yet sceptical, proofs of the same thing in the following genera, viz. *Eriphia*, *Thelphusa*, *Gegarcinus*, and *Pinnotheres* †. The three former genera, it may be observed, are foreign, which friends in the East and West Indies have enabled me to add to the first proofs of metamorphosis, by having females with ova on the point of hatching, sent home in spirits: the larvæ of these, consequently, have not been seen in the living state; but by examining such as have burst from their envelopes, without being completely developed, it is quite evident that they are *Zoea*.

With regard to the other great division of the *Decapoda*, viz. the *Macroura*, or those with extended tails, I shall only now say, that as far as my observations have gone they also undergo metamorphosis, being *Ipizopoda* when first hatched, and during the whole of their progress to the perfect animal; such is the case in *Astacus marinus*, *Palinurus*, *Palæmon Squilla*, *Crangor*, *Galathea*, *Pagurus*, and *Porcellana*.

To return to the immediate subject of the present memoir, the *Carcinus Mœnas*. In its first or *Zoè* stage it is wholly natatory from structure, while in its second it

* Zoological Researches, p. 8.

† This has since been published in the Entomological Magazine.

occasionally walks by means of its thoracic members, now become simple, but more commonly swims by the motion of its subabdominal fins, which are greatly developed for this purpose*. In both stages it is therefore a *Macroura*, but only in the latter evidently related to the *Decapoda*.

It will be quite superfluous to enter into a minute detail of the structure of this *Megalope*, further than may be collected by a reference to the figure and its accompanying explanation.

It must certainly be considered surprising that so many curious facts should have remained until the present time undiscovered; but still more, that from the first announcement of metamorphosis no person has attempted to follow it up; so that I have not only the honour of the discovery, but also the entire merit of having rendered this interesting part of the natural history of the *Crustacea* nearly complete, as the announcements in the previous part of this memoir testify, and my subsequent memoirs will prove.

The facts connected with the metamorphosis in the *Crustacea* and the *Cirripedes* are indeed so much at variance with our previous knowledge, with the dicta of some of our leading naturalists, and of so very extraordinary a nature, that the scepticism which still exists with regard to them may admit of some excuse. The approaching summer I hope will put it in my power to remove all doubts upon the subject, by submitting such of them as offer themselves to the scrutiny of *other observers*, a circumstance which never occurred to me as necessary beyond the circle of my own family; had there been any zoologists in my neighbourhood the case would have been different, but in respect of this branch of science I here unfortunately stand alone.

Whatever indifference may be charged to our own zoologists in regard to these important discoveries, we must do our scientific neighbours the French the justice of noting, that they immediately took up the subject, and two naturalists were selected and deputed to spend a summer at Isle Ré, to make their observations. However, by a subsequent report of one of these gentlemen, M. Milne-Edwards, to the French Institute, it appears that so far from verifying the metamorphosis in *Crustacea*, he pronounced that they were hatched with the form and structure of their adult parent! The observations upon which this decision was based I have not seen stated; but whatever they may have been, they are completely invalidated by the positive proofs I have given and enumerated in the present memoir.

The animals of this class are so recondite in their habits, so difficult to preserve alive for any time, so little known to naturalists beyond the more common species, that the investigation is necessarily attended with great difficulty and frequent disappointment. It must be allowed that I have been peculiarly fortunate; and I am so sensible of the obligation I owe to that Source from whence springs all our

* Fig. 3.

knowledge and intelligence, that I hasten to acquit myself of so sacred and valuable a trust with all the ability I am yet permitted to retain.

PLATE VI.

Fig. 1. *Zoe* of *Carcinus Mœnas*, magnified, and also of its natural size.
Fig. 2. *Megalope* of the same, magnified, and also of its natural size. The terminations of three pair of the subabdominal fins are only seen in the figure.
Fig. 3. One of its subabdominal fins more highly magnified.
Fig. 4. The posterior pair of fins magnified.
Fig. 5. One of its inner antennæ, highly magnified.
Fig. 6. The Young Crab, resulting from the above *Megalope*, magnified, and also of its natural size.

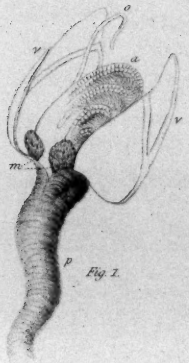

Fig. 1.

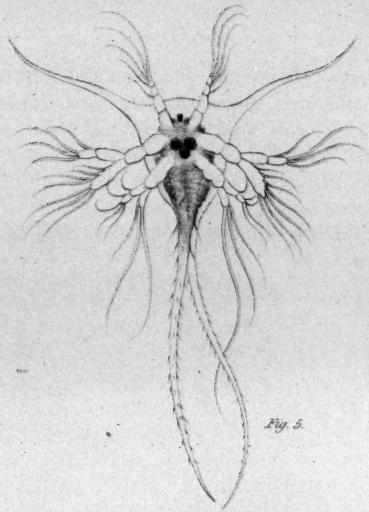

Fig. 5.

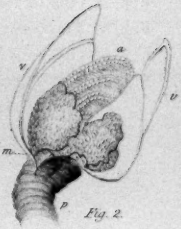

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 6.

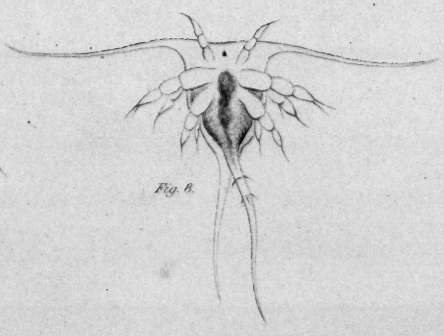

Fig. 8.

Fig. 7.

INDEX

TO THE

PHILOSOPHICAL TRANSACTIONS

FOR THE YEAR 1835.

A.

Atmospheric tides, and meteorology of Dukhun (Deccan), East Indies, on the, 161.

B.

Bakerian Lecture. On the proofs of a gradual rising of the land, &c., 1.

Bell (Sir Charles). Continuation of the paper on the relations between the nerves of motion and of sensation, and the brain; more particularly on the structure of the medulla oblongata and the spinal marrow, 255.

Brewster (Sir David), K.H. On certain peculiarities in the double refraction and absorption of light exhibited in the oxalate of chromium and potash, 91.

C.

Cirripedes, discovery of the metamorphosis in the second type of the *Lepades*, &c., 355.

Crustacea, on the supposed existence of metamorphosis in, 311.

——— (*decapodous*), on the double metamorphosis of, exemplified in *Cancer Mœnas*, Linn., 359.

D.

Daubeny (Charles, M.D.). Some account of the eruption of Vesuvius which occurred in the month of August 1834, extracted from the manuscript notes of the Cavaliere Monticelli, Foreign Member of the Geological Society, and from other sources; together with a statement of the products of the eruption, and of the condition of the volcano subsequently to it, 153.

Davies (Thomas Stephens, Esq.). Geometrical investigations concerning the phenomena of terrestrial magnetism, 221.

Differential equations of motion of an attracting or repelling system, transformations of the, 96.

Disturbing function of the fourth order, on the determination of the terms in the, &c., 57.

Double refraction and absorption of light, exhibited in the oxalate of chromium and potash, on certain peculiarities in, 91.

Dynamics, on a general method in (second essay), 95.

E.

Electric current, on its influence by induction on itself, and on the inductive action of electric currents generally, 41.

Electricity, experimental researches in. Ninth series. 41.
——————————— Tenth series. 263.
Equations of motion, integration of, by means of one principal function, 98.
Expression for the principal function in any problem of dynamics, general method of improving an approximate, 101.
Expressions, differential, simplification of, &c., 135.

F.

Faraday (Michael, D.C.L.). Experimental researches in electricity. Ninth series. 41.
——————————— Tenth series. 263.
Farquharson (Rev. James). On the ice formed, under peculiar circumstances, at the bottom of running water, 329.
Fossil shells found in Sweden, list of, 33.
Fox (R. W.). Note on the electrical relations of certain metals and metalliferous minerals, 39.

G.

Gray (John Edward, Esq.). Remarks on the difficulty of distinguishing certain genera of testaceous Mollusca by their shells alone, and on the anomalies in regard to habitation observed in certain species, 301.

H.

Hamilton (Prof. W. R.). Second essay on a general method in dynamics, 95.

I.

Ice formed, under peculiar circumstances, at the bottom of running water, on the, 329.
—— *sometimes formed* at the bottom of *still* water, note 342.

L.

Light, researches towards establishing a theory of the dispersion of, 249.
Lubbock (J. W. Esq.). On the determination of the terms in the disturbing function of the fourth order, as regards the eccentricities and inclinations which give rise to secular inequalities, 57.
——————————— Discussion of tide observations made at Liverpool, 275.
Lyell, Charles, Jun., Esq.). *The Bakerian Lecture.*—On the proofs of a gradual rising of the land in certain parts of Sweden, 1.

M.

Magnetism, terrestrial, geometrical investigations concerning the phenomena of, 221.
Metals and metalliferous minerals, note on the electrical relations of, &c., 39.

N.

Needle (*magnetic*), on the points of the earth's surface at which it takes a position vertical to the horizon, 245.
Nerves of motion and of sensation, and the brain, on the relations between, &c.—Continuation of the paper on, 255.

P.

Partial differential equations of the first order, &c., investigation of a pair of, 100.

Perturbations, rigorous theory of, &c., 102, 104, 107, 110.

POND (JOHN, Esq., A.R.). Continuation of a former paper on the twenty-five-feet zenith telescope lately erected at the Royal Observatory, 145.

POWELL (Rev. BADEN). Researches towards establishing a theory of the dispersion of light, 249.

R.

Rattlesnake, its extraordinary power of living without food, *note* 352.

Respiration, on the theory of, 345.

Rising of the land in certain parts of Sweden, on the proofs of, &c., 1.

S.

Single point, formulæ for the motion of a, 114.

STEVENS (WILLIAM, M.D.). Observations on the theory of respiration, 345.

SYKES (Lieut.-Col. W. H.). On the atmospheric tides and meteorology of Dukhun (Deccan), East Indies, 161.

System, ternary or multiple, with one predominant mass, case of a, &c., 133.

Systems, attracting, resumed, 130.

T.

Testaceous Mollusca, remarks on the difficulty of distinguishing certain genera of, by their shells alone, &c., 301.

THOMPSON (J. V., Esq.). Discovery of the metamorphosis in the second type of the *Cirripedes*, viz. the *Lepades*, completing the natural history of these singular animals, and confirming their affinity with the *Crustacea*, 355.

——————— On the double metamorphosis in the *Decapodous Crustacea*, exemplified in *Cancer Mænas*, LINN., 359.

Tide observations, made in June 1834, *at the Coast Guard Stations in Great Britain and Ireland*, on the results of, 83.

——————— discussion of some made at Liverpool, 275.

Twenty-five-feet zenith telescope, erected at the Royal Observatory, continuation of a former paper on, 145.

V.

Vesuvius, some account of the eruption of, in 1835, &c., 153.

Voltaic battery, on an improved form of, 263.

——————— some practical results respecting the construction and use of, 268.

W.

WESTWOOD (J. O., Esq.). On the supposed existence of metamorphosis in the Crustacea, 311.

WHEWELL (Rev. W.). On the results of tide observations made in June 1834 at the Coast Guard Stations in Great Britain and Ireland, 83.

Wooden house, a small one found at the depth of sixty-four feet under a stratified mass of sand, gravel, and clay, in digging the Södertelje Canal, 8.

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METEOROLOGICAL JOURNAL,

KEPT BY THE ASSISTANT SECRETARY,

AT THE APARTMENTS OF THE

ROYAL SOCIETY,

BY ORDER OF

THE PRESIDENT AND COUNCIL.

OBSERVANDA.

Height of the Cistern of the Barometer above a Fixed Mark on Waterloo Bridge.....=83 feet 2½ in.

_____ above the mean level of the Sea (presumed about) ....=95 feet.

The External Thermometer is 2 feet higher than the Barometer Cistern.

Height of the Receiver of the Rain Gauge above the Court of Somerset House.....=79 feet.

The hours of observation are of Mean Time, the day beginning at Midnight.

The Thermometers are graduated by Fahrenheit's Scale.

The Barometer is divided into inches and decimals.

METEOROLOGICAL JOURNAL FOR JANUARY AND FEBRUARY, 1835.

1835.		9 o'clock, A.M.		3 o'clock, P.M.		Dew Point at 9 A.M. in degrees of Fahr.	External Thermometer.				Rain, in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	REMARKS.
		Barom.	Attach. Therm.	Barom.	Attach. Therm.		Fahrenheit.		Self-registering.				
							9 A.M.	3 P.M.	Lowest.	Highest.			
JANUARY	T 1	30.107	51.8	30.398	51.9	48	47.9	46.0	46.3	48.6		S	A.M. Light fog and rain. P.M. Lightly cloudy—light brisk wind.
	F 2	30.794	46.4	30.819	47.3	35	40.2	42.4	38.9	41.8		N	Light fog and wind.—A.M. Overcast—light haze. P.M. Fine and clear.
	S 3	30.782	44.7	30.725	45.4	32	38.9	40.6	36.8	40.5		NE	Fine light haze and wind. P.M. Fine light clouds and wind.
	⊙ 4	30.622	40.9	30.570	41.3	29	32.9	35.2	30.2	34.5		NE	Fine and cloudless—light wind. Evening, light fog.
	M 5	30.564	38.2	30.556	40.4	32	34.3	40.3	30.6	39.4		E	Hoar frost—light fog.—P.M. Light clouds and wind. Evening, fine and clear.
	T 6	30.552	37.3	30.475	37.9	32	31.6	34.7	29.0	33.3		E	Thick fog.—P.M. Light haze.
	W 7	30.307	35.0	30.212	34.3	27	27.9	29.9	25.8	28.5		E	Thick fog.—P.M. Light rain. Evening, frosty.
	T 8	30.128	33.2	30.063	34.6	29	30.0	33.7	25.0	35.8		ENE	Sharp frost—light fog and wind.
	F 9	29.875	36.7	29.703	38.6	32	37.2	44.0	28.4	47.5		S	Lightly cloudy—thaw.—A.M. Overcast. P.M. Light rain.
	S 10	29.825	40.6	29.841	42.2	36	38.9	43.8	35.8	46.9	.113	SSW	A.M. Fine—light clouds with light brisk wind. P.M. Overcast—drizzling rain.
	⊙ 11	29.800	44.6	29.853	46.2	42	46.8	50.3	37.2	49.6		S var.	A.M. Lightly overcast—light unsteady wind. P.M. Light rain.
	M 12	29.930	46.4	29.918	47.8	44	47.8	49.0	45.7	49.7		SW	Overcast—deposition.—A.M. Fine light clouds. P.M. Lightly cloudy—light wind.
	T 13	29.707	46.3	29.594	46.7	40	40.2	45.4	39.8	45.3		ESE	A.M. Fine—light clouds and wind. P.M. Lightly overcast.
	● W 14	29.479	47.2	29.473	48.8	42	45.7	49.4	39.9	48.8		SE	Overcast—deposition.—P.M. Overcast—very light rain.
	T 15	29.656	48.7	29.693	49.8	43	46.6	48.3	44.2	47.8		SW	A.M. Lightly cloudy. P.M. Fine light clouds and wind.—High wind throughout the night.
	F 16	29.091	48.8	29.197	49.6	44	47.2	44.2	44.2	49.6		SW var.	Overcast—very light rain.—A.M. Fine light clouds. P.M. Fine and cloudless—light haze.
	S 17	29.598	43.2	29.685	44.6	38	35.2	40.3	31.9	39.3		SW	Fine—light clouds and wind. Evening, sharp frost.
	⊙ 18	29.808	39.2	29.604	40.3	27	31.5	36.6	27.8	42.2		ESE	Hoar frost—light haze.—P.M. Lightly overcast. Evening, light snow and rain.
	M 19	29.101	40.7	29.172	41.6	35	39.9	38.8	29.5	42.3		SW var.	Lightly cloudy.—A.M. Overcast—light unsteady wind. P.M. Cloudy—deposition.
	T 20	30.083	37.3	30.091	38.0	26	32.0	33.5	30.5	32.4		NE var.	Fine & frosty—light brisk wind. Even. fine & clear—sharp frost.
	W 21	30.328	34.7	30.253	35.7	17	27.4	31.9	24.9	35.7		SW	A.M. Fine and frosty—light fog. P.M. Light fog. Evening, snow—sharp frost.
	T 22	30.134	36.6	30.220	38.4	33	37.2	39.2	25.3	38.6		NE	Overcast—light wind.
	F 23	30.344	38.6	30.301	39.9	32	38.8	41.4	33.8	44.2		SW	Light fog.—Evening, overcast—light rain.
	S 24	30.115	41.7	30.154	43.8	40	45.4	47.6	37.2	47.6	.069	SW	Overcast—deposition.—A.M. Fine light clouds and wind. P.M. Overcast—very light rain.
	⊙ 25	30.200	43.6	30.214	45.4	39	45.3	49.9	37.2	49.7		S	Overcast—deposition—light wind.
	M 26	30.332	45.6	30.332	47.4	41	47.7	48.7	42.8	49.7		SW	Fine—light clouds.
	T 27	30.425	46.2	30.406	47.3	37	44.5	46.6	40.6	45.9		SW	Overcast—light fog. P.M. Light clouds and wind.
	○ W 28	30.362	45.3	30.279	46.2	37	40.9	47.0	38.6	41.7		SW	Overcast—deposition.
	T 29	30.188	45.0	30.128	46.9	38	42.0	48.2	39.8	47.7		S var.	Fine—lightly cloudy—light haze.—A.M. Fine and cloudless—light haze. P.M. Fine light clouds.
	S 30	30.087	46.3	30.035	48.3	41	44.2	46.4	40.8	47.6		S var.	A.M. Light fog and wind. P.M. Fine and cloudless—light haze. Evening, cloudy.
	S 31	30.000	44.0	30.047	45.5	36	38.6	42.0	35.0	43.6		S	Overcast—light fog and wind.
	MEANS ..	30.075	42.4	30.065	43.6	35.6	39.5	42.4	35.3	43.1	Sum. .182	Mean of Barometer, corrected for Capillarity and reduced to 32° Fahr.	9 A.M. 30.048 / 3 P.M. 30.034
FEBRUARY	⊙ 1	30.275	46.0	30.269	48.2	41	44.7	50.0	36.9	49.6		S var.	Overcast—light rain and wind.—P.M. Fine—lightly cloudy. Evening, overcast.
	M 2	30.142	48.4	30.178	50.3	45	50.2	53.2	43.3	53.2		SW	A.M. Overcast—light rain and wind. P.M. Lightly overcast.
	T 3	30.352	47.7	30.376	50.0	43	45.0	51.2	42.2	50.6		SW	Fine—light clouds and wind.
	W 4	30.459	48.0	30.441	50.2	40	43.2	50.3	41.0	50.2		SW	A.M. Fine—light clouds and fog. P.M. Fine and clear—light clouds and wind.
	T 5	30.200	48.0	30.033	50.3	42	45.6	50.9	40.7	50.8		SW var.	Fine—light clouds with light brisk wind.—A.M. Cloudy. P.M. Fine and clear—light wind.
	F 6	30.172	44.6	30.259	46.2	30	38.0	43.7	35.2	45.4		S var.	A.M. Fine & clear—light haze & wind. P.M. Fine lt. clds. & wind.
	S 7	30.067	46.2	29.918	48.3	39	46.6	50.9	36.8	50.5		SW	Lightly overcast—light wind. Evening, cloudy.
	⊙ 8	29.697	47.0	29.661	48.3	32	42.6	44.7	40.8	46.2		WSW	Fine and clear—light haze & wind. Evening, cloudy—light rain.
	M 9	29.849	43.0	29.922	44.3	27	36.7	41.0	33.8	39.8	.061	SW	A.M. Fine and cloudless—light haze and wind. P.M. Fine and cloudless—light brisk wind. Evening, fine and frosty.
	T 10	30.091	38.6	30.255	40.6	22	32.4	39.5	29.8	38.2		NE var.	Fine—sharp frost—light brisk wind—snow during the night. Evening, fine and clear—sharp frost.
	W 11	30.435	37.8	30.372	41.3	24	33.3	41.9	27.9	44.7		S	Cloudy—light frost and wind.
	T 12	30.132	43.2	30.168	44.5	35	46.0	45.2	31.8	46.3		SW	Overcast—light rain and wind. Evening, fine and clear.
	○ F 13	30.336	41.9	30.247	45.2	32	39.3	46.3	35.0	46.8	.125	SW	A.M. Fine and cloudless—light haze and wind. P.M. Overcast.
	S 14	30.014	44.9	29.917	46.6	40	43.4	49.4	37.5	49.8		SW	Overcast—light rain.
	⊙ 15	29.701	48.2	29.956	50.2	42	47.6	51.0	42.3	51.4		SW	Overcast—deposition.—A.M. Fine—light clds. Even. overcast.
	M 16	29.530	46.3	29.592	48.0	40	43.2	46.2	40.0	47.3		NW var.	A.M. Lightly cloudy. P.M. Overcast—light brisk wind.
	T 17	29.711	45.9	29.728	48.0	40	42.4	45.8	38.6	46.7		S var.	Overcast—drizzling rain.—A.M. Fine and clear. P.M. Cloudy.
	W 18	29.469	46.3	29.461	48.4	40	44.6	49.2	38.8	49.3		S var.	Overcast—light rain—brisk wind. Evening, cloudy.
	T 19	29.465	45.0	29.396	48.0	38	41.3	47.5	35.7	48.3		SW	Fine—nearly cloudless.—A.M. Overcast. P.M. Fine—light clds.—brisk wind. Eve. overcast—heavy rain—high wind.
	F 20	29.273	45.0	29.271	47.6	34	39.9	47.6	37.0	48.2	.061	WSW	Fine & cloudless.—A.M. Lightly overcast. P.M. Fine—light clouds & wind. Eve. overcast—light rain—high wind.
	S 21	29.295	43.3	29.346	46.4	34	38.4	43.7	33.2	45.8	.133	WSW	Fine and cloudless—light wind. Evening, cloudy.
	⊙ 22	29.758	42.7	29.614	45.9	35	38.8	43.8	34.2	49.5		WSW	Fine & cloudless—lt. haze & wind.—A.M. Cldy. P.M. Overcast—light rain. Eve. rain—high wind throughout the night.
	M 23	29.267	45.6	29.483	48.2	39	46.3	48.6	37.0	49.6	.033	SW var.	A.M. Fine—light clouds—high wind. P.M. Fine—nearly cloudless. Evening, cloudy—high wind.
	T 24	29.780	43.2	29.827	45.8	32	38.4	45.4	33.9	45.3		WSW	Fine—light clouds and haze. P.M. Lightly cloudy—high wind.
	W 25	29.604	44.8	29.412	46.9	40	46.2	49.4	36.0	49.3		SE var.	A.M. Cloudy—high wind. P.M. Overcast—light drizzling rain and wind.
	T 26	29.287	46.5	29.459	49.0	40	44.6	48.5	42.8	49.7		W	Fine—light clouds and wind. Eve. very light rain—high wind.
	● F 27	29.227	45.9	29.279	48.5	40	44.4	49.8	38.4	49.3		SW var.	A.M. Overcast—strong wind. P.M. Fine—light clouds & wind.
	S 28	29.685	44.8	29.817	46.6	31	41.2	45.2	37.2	44.7		S var.	Fine and clear—light clouds and wind.—Evening, cloudy, light brisk wind.
	MEANS ..	29.831	45.0	29.845	47.2	36.3	42.3	47.1	37.1	47.7	Sum. .413	Mean of Barometer, corrected for Capillarity and reduced to 32° Fahr.	9 A.M. 29.796 / 3 P.M. 29.803

METEOROLOGICAL JOURNAL FOR MARCH AND APRIL, 1835.

1835.		9 o'clock, A.M.		3 o'clock, P.M.		Dew Point at 9 A.M. in degrees of Fahr.	External Thermometer.				Rain, in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	REMARKS.
		Barom.	Attach. Therm.	Barom.	Attach. Therm.		Fahrenheit.		Self-registering.				
							9 A.M.	3 P.M.	Lowest.	Highest.			
⊙	1	29.257	42.9	29.364	43.6	32	36.8	38.7	34.8	38.3		SW	Overcast—light rain and snow.
M	2	30.150	40.6	30.079	42.7	33	35.5	41.6	32.7	47.9		WSW	Overcast—deposition—light wind. Evening, cloudy.
T	3	29.677	45.2	29.780	46.4	34	47.3	45.9	34.6	47.2	.027	SW var.	A.M. Fine—light clds.—high wind. P.M. Fine—nearly cloudless.
W	4	29.887	42.5	29.639	45.3	36	40.3	47.8	35.7	46.8		SW	A.M. Fine—light clouds and wind. P.M. Overcast—heavy rain.
T	5	29.974	40.6	29.978	43.9	29	38.6	45.2	33.8	45.8	.101	SW var.	Fine and cloudless—light haze and wind. Evening, Overcast —very light rain.
F	6	29.378	44.7	29.588	47.2	38	43.5	49.2	37.2	49.6		W	Fine—light clds—brisk wind. Ev. overcast—light rain and wind.
S	7	29.011	45.5	28.855	47.3	38	46.2	45.5	40.0	47.8		S var.	A.M. Lightly overcast—brisk wind. P.M. Overcast—rain and hail—brisk wind.
⊙	8	29.798	42.0	29.827	44.9	32	38.4	44.2	34.2	44.2		SW var.	Fine and cloudless—light haze and wind. Evening, overcast —high wind.
M	9	29.261	44.6	28.912	46.0	38	45.2	48.2	37.2	48.4		SE	Cloudy—very light rain and wind. Evening, fine and clear.
T	10	29.495	41.8	29.602	45.0	31	38.2	45.8	32.7	47.6		WSW	Fine and cloudless—light wind. Evening, very high wind.
W	11	29.550	44.8	29.508	47.2	42	48.5	49.9	36.9	52.7		S var.	Overcast—very light rain and unsteady wind.
T	12	29.756	45.6	29.701	48.8	42	46.3	50.7	40.5	53.4		NW var.	Overcast—light rain and wind. Evening, fine and clear.
F	13	30.160	45.6	30.218	48.8	36	41.4	48.8	37.2	49.2	.011	SW	A.M. Fine—light fog. P.M. Fine—light clouds and wind.
○	14	29.994	46.5	29.998	49.7	41	45.2	54.6	40.0	54.2		SE var.	A.M. Overcast—deposition—light wind. P.M. Fine and clear.
⊙	15	29.837	47.8	29.908	50.0	41	46.2	49.3	43.9	49.5		S	A.M. Overcast—light rain. P.M. Fine—light clouds and wind.
M	16	30.067	46.6	30.051	49.5	39	45.0	49.9	38.9	50.6		WSW	A.M. Fine and clear—light clouds. P.M. Lightly overcast.
T	17	29.893	47.5	29.742	48.8	40	45.7	50.2	43.0	49.7		S var.	Overcast—very light rain—unsteady wind.
W	18	29.930	45.9	30.004	48.7	38	43.3	47.7	39.9	48.6		N var.	A.M. Lightly overcast—light brisk wind. P.M. Cloudy—brisk wind. Evening, fine and clear.
T	19	30.259	43.2	30.247	44.2	30	36.6	42.5	34.7	44.7		N	Foggy.
F	20	30.334	45.0	30.307	48.4	38	45.8	52.2	35.0	52.3		S	A.M. Lightly overcast. P.M. Thick haze.
S	21	30.243	47.3	30.208	49.1	42	48.2	51.0	45.2	51.3		SW	Overcast—very light rain.
⊙	22	30.261	47.8	30.257	48.7	41	45.9	46.4	43.9	47.6		ENE	A.M. Thick fog. P.M. Overcast—light rain—brisk wind.
M	23	30.259	45.5	30.229	48.2	40	43.7	47.4	37.4	47.7		NNE	A.M. Lightly overcast—light wind. P.M. Fine—light clouds. Evening, cloudy.
T	24	30.219	44.8	30.360	47.3	38	42.7	45.0	39.0	46.0		E	Overcast—very light rain—brisk wind. P.M. Fine—light clouds and wind.
W	25	30.540	42.3	30.532	45.5	33	39.8	47.9	32.9	47.3		N	Fine—light clouds and haze. Evening, cloudy.
T	26	30.474	41.8	30.372	44.9	34	36.5	47.6	32.9	46.8		S	A.M. Lightly overcast. P.M. Fine and cloudless—light haze.
F	27	30.344	44.2	30.301	47.0	38	42.5	49.2	35.7	49.3		ENE	A.M. Thick fog. P.M. Cloudy—light wind.
S	28	30.216	44.0	30.130	45.8	35	42.2	43.7	38.7	43.6		E	Cloudy—light brisk wind.
●	⊙ 29	30.090	43.3	30.018	46.2	34	41.4	44.7	34.2	45.2		E	A.M. Fine—light clouds—haze and wind. P.M. Cloudy—light wind.
M	30	29.871	41.4	29.806	45.2	31	39.6	50.5	33.0	50.6		E	A.M. Fine—thick haze. P.M. Fine—nearly cloudless.
T	31	29.816	45.3	29.720	47.7	37	47.8	51.6	36.9	54.2		SSW	A.M. Fine—lightly cloudy. P.M. Overcast—light rain.
MARCH	MEANS..	29.936	44.4	29.914	46.8	36,5	42.7	47.5	37.2	48.3	Sum. .139	Mean of Barometer, corrected for Capillarity and reduced to 32° Fahr. ..: ..	9 A.M. 29.903 / 3 P.M. 29.874
W	1	29.966	50.0	29.952	53.2	48	54.0	61.3	47.2	62.8		SSW	Fine—light clouds and wind.
T	2	29.881	53.8	29.804	56.4	49	55.7	65.3	48.6	66.2		S	A.M. Fine—light fog. P.M. Overcast. Evening, Light rain.
F	3	29.804	56.8	29.823	59.0	50	56.2	59.4	52.7	61.4		SW	Overcast, Evening, Light rain.
S	4	30.130	54.6	30.148	55.4	48	49.0	52.8	48.0	52.6		ENE	Overcast—light rain and wind.
⊙	5	30.214	52.3	30.249	53.7	47	48.0	49.3	45.3	49.2	.094	E	Overcast—light rain and wind.
M	6	30.328	51.3	30.366	54.5	42	48.4	57.0	40.4	57.2	.033	E	A.M. Fine and cloudless—light haze. P.M. Lightly overcast. Evening, Fine and clear.
T	7	30.410	50.6	30.352	54.5	42	49.3	59.9	41.8	60.4		E	Fine and cloudless—light haze. Evening, Fine and clear.
W	8	30.344	54.9	30.263	57.0	44	54.3	64.7	43.4	64.7		SW	Fine and cloudless—light haze. Evening, Fine and clear.
T	9	30.210	56.1	30.148	58.9	47	54.7	61.2	45.8	62.6		SSW	Fine—light clouds and wind. Evening, Cloudy.
F	10	30.182	56.7	30.212	59.3	51	55.0	58.2	52.8	58.8		WSW	A.M. Overcast—light wind. P.M. Fine—light clouds and wind. Evening, Fine and clear.
S	11	30.348	54.0	30.380	54.8	39	47.3	50.0	41.2	60.8		NE var.	Fine—light clouds and wind. Evening, Fine and clear.
⊙	12	30.317	52.2	30.237	54.5	39	46.0	56.2	36.8	55.8		SW	Fine and cloudless—light haze.
○	M 13	30.196	52.7	30.152	55.4	44	49.3	58.7	40.8	61.0		SW	A.M. Fine and cloudless—light haze. P.M. Cloudy. Evening, Fine and clear.
T	14	30.188	55.6	30.091	57.0	38	53.3	61.5	45.0	61.8		S	Fine and cloudless—light haze.
W	15	29.944	54.7	29.911	56.8	43	49.4	51.0	42.0	59.6		WSW	A.M. Thick haze. P.M. Overcast—light brisk wind. Evening, Light rain.
T	16	30.206	48.6	30.130	49.8	26	39.7	46.5	32.8	46.7	.033	NE	A.M. Fine & cldless—li.haze. P.M. Overcast—snow—hail & rain.
F	17	30.186	46.5	30.176	47.3	29	38.0	40.2	30.0	43.8	.144	NE	A.M. Fine—light clouds and wind. P.M. Snow—light wind. Evening, Fine and clear.
S	18	30.082	46.3	29.964	48.2	36	44.3	48.0	34.8	49 7		SW	Fine—lightly cloudy. Evening, Overcast—light rain.
⊙	19	30.295	49.6	30.358	50.7	34	45,3	51.4	37.0	51.3	.027	NE var.	A.M. Fine—light clouds and wind. P.M. Cloudy. Evening, Fine and clear.
M	20	30.473	48.7	30.467	52.4	42	49.8	56.3	44.3	57.3		SW	A.M. Thick haze. P.M. Cloudy—light wind.
T	21	29.462	51.3	30.425	53.9	43	51.2	56.7	45.5	56 9		SW	Cloudy—light rain and wind.
W	22	30.445	52.5	30.420	55.5	47	52.7	58.6	46.0	59.6	.061	NNE	A.M. Fine—light clouds and wind. P.M. Cloudy.
T	23	30.465	55.6	30.402	55.3	42	53.3	53.4	45.2	55.7		WNW	Overcast—light wind.
F	24	30.388	54.0	30.309	56.8	47	52.8	57.4	48.3	59.4		SW	A.M. Thick haze. P.M. Cloudy—light brisk wind.
S	25	30.148	58.0	30.029	56.6	38	52.0	51.5	46.2	55.4		NW var.	Fine—light clouds and wind. Evening, Overcast—light wind.
⊙	26	29.718	51.0	29.675	52.3	34	44.4	47.6	40.2	47.8		NW	A.M. Cloudy—brisk wind. P.M. Overcast—hail and light rain.
●	M 27	29.631	50.3	29.621	50.6	32	43.4	47.5	34.2	48.2		NE	A.M. Fine and cloudless—light haze & wind. Evening, Cloudy.
T	28	29.835	50.3	29.808	51.4	33	45.4	50.7	34.4	51.2		NE	Fine—light clouds & light brisk wind. Evening, Fine and clear.
W	29	29.679	46.4	29.627	48.8	41	44.4	46.8	39.6	46.6		NNE var.	A.M. Overcast—light rain and wind. P.M. Lightly overcast. Evening, Overcast—light steady rain.
T	30	29.528	48.6	29.556	50.6	45	47.2	49.6	41.9	50.2	.677	ENE	A.M. Overcast—light steady rain. P.M. Overcast. Evening, Overcast—light steady rain.
APRIL	MEANS..	30.133	52.1	30.102	54.0	41.3	49.1	54.3	42.4	55.8	Sum. 1.069	Mean of Barometer, corrected for Capillarity and reduced to 32° Fahr.	9 A.M. 30.077 / 3 P.M. 30.040

METEOROLOGICAL JOURNAL FOR MAY AND JUNE, 1835.

1835.		9 o'clock, A.M.		3 o'clock, P.M.		Dew Point at 9 A.M. in degrees of Fahr.	External Thermometer.				Rain in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	REMARKS.
		Barom.	Attach. Therm.	Barom.	Attach. Therm.		Fahrenheit.		Self-registering.				
							9 A.M.	3 P.M.	Lowest.	Highest.			
	F 1	29.635	50.0	29.649	53.0	46	47.4	52.3	44.6	52.6	.158	SW	Overcast—very light rain and wind.
	S 2	29.647	51.7	29.626	54.6	45	51.5	54.5	44.0	57.8		S	A.M. Fine—light clouds. P.M. Overcast—light rain and wind.
	⊙ 3	29.770	54.2	29.804	55.5	43	51.9	53.6	45.0	53.6	.036	WNW	Overcast—light wind.
	M 4	29.883	56.2	29.922	56.3	43	52.5	54.3	44.7	59.2		SW	A.M. Fine—light clouds. P.M. Overcast—light brisk wind.
	T 5	30.109	54.6	30.083	57.4	44	49.5	58.5	45.0	59.7		NE	Overcast—light rain and wind.
	W 6	29.865	54.7	29.835	58.6	49	53.6	61.4	48.9	62.3	.133	S	A.M. Lightly overcast—very light rain. P.M. Fine—light clouds. Evening, Fine and clear.
	T 7	29.968	60.5	30.008	60.3	48	56.6	60.9	45.6	61.2		SW	A.M. Fine—light clouds and wind. P.M. Cloudy. Evening, Fine and clear.
	F 8	30.109	60.3	30.079	61.6	51	55.4	63.5	46.0	63.9		SSW	Overcast—Evening, Fine and clear.
	S 9	30.004	64.3	29.913	64.7	55	62.6	67.2	54.5	68.4		S	Fine—light clouds.
	⊙ 10	29.816	63.6	29.794	65.0	49	59.8	64.8	50.0	65.6		SW	A.M. Fine—light clouds. P.M. Cloudy. Evening, Fine and clear.
	M 11	29.984	64.5	29.972	64.2	50	57.0	60.6	45.7	63.7		SW	A.M. Fine—lightly cloudy. P.M. Overcast—light rain.
	○ T 12	29.833	59.6	29.766	63.6	50	57.2	60 8	52.4	63.6	.033	SW	Fine—light clouds & wind. Even. Overcast—light steady rain.
	W 13	29.604	65.3	29.631	64.0	48	59 3	61.8	50.9	63.2	.097	SW	A.M. Lightly overcast—light brisk wind. P.M. Fine—light clouds and wind. Evening, Overcast—heavy rain.
	T 14	29.495	55.2	29.558	56.2	47	48.9	48.4	45.4	55.0	1.033	E	A.M. Overcast—light steady rain. P.M. Overcast—heavy rain, with distant thunder and lightning.
MAY	F 15	29.720	56.6	29.730	58.8	47	54.5	56.5	45.2	58.6	.369	S	A.M. Fine—light clouds and wind. P.M. Thunder, accompanied with heavy rain. Evening, Cloudy.
	S 16	29.774	59.8	29.829	60.7	48	58.5	63.2	47.4	63.2	.183	S	Fine—light clouds. Evening, Fine and clear.
	⊙ 17	30.004	65.5	29.976	62.2	50	59.8	64.0	46.8	64.5		SE var.	Fine—nearly cloudless.
	M 18	29.930	63.9	29.885	64.0	50	65.0	70.0	48.4	72.8		E	A.M. Fine and cloudless—light haze. P.M. Fine—lightly cloudy—light brisk wind.
	T 19	29.873	63.2	29.851	65.2	52	63.9	66.6	54.2	68.7		E	Fine—light clouds and wind.
	W 20	29.942	59.9	29.976	62.4	53	55.6	60.9	52.8	61.8		E	Overcast—light rain and wind.
	T 21	30.208	62.8	30.200	64.2	49	56.7	61.3	50.3	62.3	.047	E	A.M. Fine—light clouds and wind. P.M. Cloudy—light brisk wind.
	F 22	30.174	62.8	30.103	63.5	46	55.4	65.5	47.6	66.7		N	A.M. Thick haze. P.M. Fine—light clouds and wind. Evening, Overcast—light rain.
	S 23	30.186	64.3	30.128	66.0	53	60.7	68.2	52.6	69.6	.052	NNE	Fine—light clouds. Evening, Cloudy.
	⊙ 24	30.156	66.5	30.075	66.8	56	66.6	70.4	55.7	71.4		S	Fine—light clouds. Evening, Cloudy.
	M 25	29.881	64.6	29.770	66.2	50	60.6	65.2	56.0	66.4		SW	A.M. Cloudy. P.M. Fine—light clouds and wind. Evening, Cloudy—very light rain.
	T 26	29.542	62.4	29.456	62.8	50	55.9	58.0	48.6	58.6		SW	Overcast—light rain and wind.
	● W 27	29.695	60.6	29.748	62.7	50	55.7	59.5	46.2	61.6	.097	SW	A.M. Cloudy—light wind. P.M. Overcast—thunder and lightning—heavy rain.
	T 28	29.656	58.3	29.968	61.2	49	54.8	56.0	46.2	58.7	.241	E	Cloudy—light brisk wind. Evening, Fine and clear.
	F 29	30.069	59.4	30.077	61.2	43	54.1	58.8	43.0	59.8		NE	Fine—light clouds and wind. Evening, Cloudy.
	S 30	30.103	59.5	30.061	60.0	40	52.2	57.7	41.7	58.0		N	A.M. Cloudy—light brisk wind. P.M. Fine—light clouds and wind. Evening, Fine and clear.
	⊙ 31	30.045	58.3	29.966	60.8	42	54.7	60.4	43.8	64.2		S	A.M. Fine—light clouds and wind. P.M. Cloudy. Evening, Overcast—light rain.
	MEANS..	29.893	60.1	29.885	61.4	48.3	56.4	60.8	48.0	62.5	Sum. 2.479	Mean of Barometer, corrected for Capillarity and reduced to 32° Fahr.	9 A.M. 29.813 / 3 P.M. 29.801
	M 1	29.911	56.2	29.954	58.9	48	52.7	56.6	48.6	62.8	.116	S	Overcast—light rain and wind.
	T 2	30.047	61.6	30.027	62.0	50	63.0	66.3	46.0	66.7	.063	ESE	A.M. Fine—light clouds. P.M. Overcast—light rain.
	W 3	29.901	58.6	29.897	62.4	52	58.8	67.6	52.7	68.4	.200	E	A.M. Overcast—light rain. P.M. Fine—light clouds & wind. Evening, Cloudy.
	T 4	30.006	62.7	30.023	64.5	58	61.8	63.8	55.9	65.3		N	Lightly overcast—light rain and wind.
	F 5	30.083	59.6	30.081	63.4	53	55.7	61.7	50.5	65.2	.036	S var.	Overcast—light brisk wind. Evening, Fine and clear.
	S 6	30.079	65.2	30.071	67.2	59	65.3	75.2	52.8	75.5		NE	Fine and cloudless—light haze and wind.
	⊙ 7	30.160	67.6	30.130	69.6	60	65.3	75.9	57.7	77.3		N	Fine light clouds and haze, with distant thunder. Evening, Fine and clear.
	M 8	30.141	74.3	30.113	72.8	75	74.0	78.6	60.6	80.2		N	Fine and cloudless—light wind.
	T 9	30.239	75.8	30.208	74.5	64	75.0	79.3	62.8	80.6		S	Fine—light haze and wind. Evening, Fine and clear.
	○ W 10	30.331	76.6	30.321	75.4	63	75.2	81.7	62.0	81.8		E	Fine and cloudless—light brisk wind.
	T 11	30.394	77.2	30.378	77.2	66	77.2	82.3	65.4	83.6		N	Fine and cloudless—light haze and wind.
	F 12	30.416	77.0	30.370	77.6	65	75.3	81.7	63.4	82.2		N	A.M. Fine and cloudless—light haze and wind. P.M. Fine—light clouds. Evening, Cloudy.
	S 13	30.352	68.2	30.299	72.0	58	58.9	69.2	57.0	69.9		N	A.M. Overcast—light wind. P.M. Fine—light clouds. Evening, Cloudy.
JUNE	⊙ 14	30.285	67.3	30.214	69.7	50	59.6	70.6	52.6	71.5		N	Fine—light clouds and wind. Evening, Cloudy.
	M 15	30.237	72.4	30.221	72.9	61	68.8	74.7	59.4	75.4		NE	A.M. Cloudy—light brisk wind. P.M. Fine—light clouds. Evening, Cloudy.
	T 16	30.295	76.6	30.244	74.2	58	70.2	74.0	60.0	75.8		NW	Fine light clouds and wind. Evening, Overcast—heavy rain during night.
	W 17	30.154	73.0	30.111	74.5	63	71.6	73.7	65.2	75.9	.133	N	Fine—light clouds—brisk wind. Evening, Overcast—light shower, with distant thunder.
	T 18	30.115	68.4	30.103	72.6	58	62.6	70.0	57.5	70.8	.027	NE	Cloudy—light wind. Evening, Fine and clear.
	F 19	30.202	74.7	30.172	71.6	50	63.2	67.8	54.9	69.2		NE	Fine—light clouds. Evening, Cloudy.
	S 20	30.010	67.0	29.980	70.3	53	62.6	70.0	58.2	70.8		SW	A.M. Lightly overcast. P.M. Fine light clouds and wind. Evening, Cloudy.
	⊙ 21	30.095	74.2	30.010	70.6	52	64.2	71.9	51.8	72.5		SW	A.M. Cloudy—light wind—P.M. Fine—nearly cloudless. Evening, Cloudy.
	M 22	29.853	67.7	29.768	70.5	58	65.2	72.4	58.2	73.7		SW	A.M. Cloudy—light brisk wind. P.M. Fine—light clouds and wind. Evening, Overcast—heavy rain and wind.
	T 23	29.681	69.2	29.724	69.4	52	62.8	65.3	55.3	67.8	.391	SW var.	Fine—light clouds, and light brisk wind.
	W 24	29.542	63.7	29.215	64.3	53	58.6	60.4	49.3	60.8		ESE	A.M. Overcast—light rain—brisk wind. P.M. Heavy rain—very high wind. Evening, Overcast—light continued rain.
	T 25	29.447	67.2	29.548	60.5	45	54.7	53.6	46.7	59.6	.352	W	Overcast—light rain throughout the day.
	● F 26	29.901	67.5	29.742	62.2	45	59.3	52.3	44.6	62.6	.250	SW	A.M. Fine—light clds. P.M. Overcast—heavy rain & high wind.
	S 27	30.012	65.9	30.111	62.2	46	55.2	55.5	45.4	59.8	.630	SW	A.M. Fine—light clouds & wind. P.M. Cloudy—light showers.
	⊙ 28	30.269	65.2	30.247	62.7	45	58.3	61.8	47.4	62.8		WSW	A.M. Fine—light clouds and wind. P.M. Cloudy.
	M 29	30.253	64.3	30.190	63.3	48	58.2	62.7	46.3	63.7		E	A.M. Fine—light clouds and wind. P.M. Cloudy.
	T 30	30.162	64.0	30.119	64.9	46	62.3	66.0	50.4	68.3		E	Fine—light clouds and wind.
	MEANS..	30.086	68.3	30.053	68.5	55.1	63.9	68.8	54.6	70.7	Sum. 2.198	Mean of Barometer, corrected for Capillarity and reduced to 32° Fahr.....	9 A.M. 29.981 / 3 P.M. 29.948